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TRICHOPTILUS PYGMAEUS WLSM.
AND
THE NEURATION OF THE FAMILY PTEROPHORIDAE

A. W. LINDSEY

When "The Pterophoridae of America, North of Mexico" was published, two specimens of *T. pygmaeus* were available to the authors, one in the collection of the United States National Museum and the other in the Fernald collection from the type lot. It was gratifying, therefore, to receive from Mr. E. H. Blackmore a series of ten specimens taken at Shawnigan, Vancouver Is., July 18, 1923. This is but one of many valuable results of Mr. Blackmore's diligent collecting and careful study for which the writer expresses his hearty appreciation and thanks.

An examination of the specimens corroborated Mr. Blackmore's identification. The opportunity which they furnish for the accurate determination of the generic characters of *Trichoptilus* has apparently not been enjoyed by anyone else, excepting possibly Lord Walsingham himself, for Professor Fernald had not removed the wings from the single specimen now in his collection, and there is no reason to believe that others exist where they are available for scientific scrutiny. Mr. T. Bainbrigge Fletcher (in litt.) states that he uses *Buckleria* Tutt for the other species commonly placed in the genus, retaining *Trichoptilus* for its type alone. His reason, ample, to be sure, is that Lord Walsingham compared the species concerned and agreed with his views. In order to settle this point, the right wings of one specimen were removed and mounted for microscopic examination, and this led to the surprising results here recorded.

The first wings prepared showed only a single long vein running to the tip of the second lobe of the primaries, apparently M_3+Cu_1, according to later discoveries. They were otherwise similar to those of *T. lobidactylus* Fitch excepting the evanescent tips of R_2 and R_1 and bases of both anals. The complete loss of a vein from the second lobe seemed to justify the separation of the genera as practiced by Mr. Fletcher, but to my surprise, other

specimens showed variations in neuration. One had Cu_2 well marked, tubular, though weak, but this specimen lacked R_1. Other wings were then examined which showed no trace either of R_1 or Cu_2. The figure (Text fig. 1) is therefore a composite showing all veins known to appear in this species. It will be seen that it differs so little from the wings of other species now

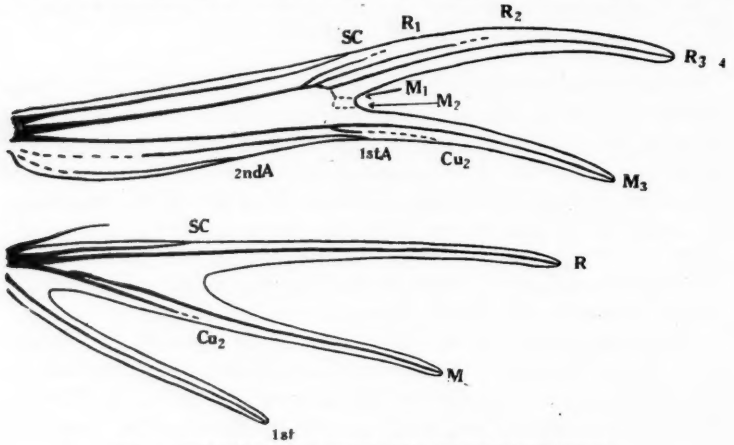


FIG. 1. TRICHOPTILUS PYGMAEUS WLSM NEURATION.

included in the genus (Plate XX, fig. 1) that the retention of the present association is justified. The condition of the neuration indicates, however, that *pygmaeus* is in a state of evolution which may ultimately produce a much simpler wing than is now found in the species.

In consideration of the diversity of genitalic structure exhibited by the North American species, no analysis of relationships can be drawn from this source. The genitalia of *pygmaeus* are figured (Text fig. 2) for specific identifications. The figure is taken from a camera drawing of a prepared specimen which was slightly distorted on the slide. No appreciable asymmetry is actually present.

It occurred to the writer while working on the wings of this species that the neuration of the Pterophoridae as treated by Meyrick in the Genera Insectorum and by Barnes and Lindsey in the Pterophoridae of America is probably incorrectly interpreted. Our North American genera furnish enough types of neuration to illustrate the problem nicely, and Plate XX, a re-

production of Plate XLVIII of the Pterophoridae of America, shows examples of each genus. The writer is indebted to Dr. Wm. Barnes for the use of the cut for this plate.

In Fig. 10 are shown the wings of the only North American species without clefts. It will be noted that R_5 reaches the apex

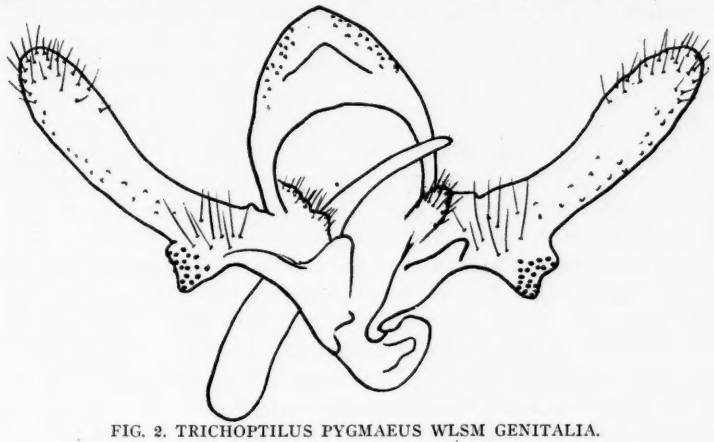


FIG. 2. TRICHOPTILUS PYGMAEUS WLSM GENITALIA.

of the primaries, M_1 and M_2 are weak, M_3 and Cu_1 are long stalked, and 1st and 2nd A vestigial. This suggests that some veins may be lost by independent reduction and others by progressive anastomosis, as is so often the case in the Lepidoptera. In the secondaries vestigial veins are even better illustrated, and one median, probably M_2, is completely lost.

The problems suggested by the comparison of wings of the cleft-winged genera are mostly simple. M_1 and M_2 are usually faintly evident as thickened lines at the base of the cleft in the primaries, and in *Oidaematophorus* alone of our genera is one of them, M_1, tubular. M_3 persists, showing a tendency to stalking with Cu_1. In no example is there evidence of extreme coalescence of these veins which would suggest incipient coincidence. On the contrary *Adaina* shows both Cu_1 and Cu_2 in a vestigial state, indicating the limitation of coalescence of the former with M_3 and the reduction of both cubital branches by independent change. Unfortunately none of our genera in the Oidaematophorid series (Spuler's Pterophorinae), including the genera with two anals in the secondaries, appear to be derived from this genus, so the possible results cannot be followed out. In the remaining genera

there is nothing to show the fate of the cubitals except several degrees of stalking of Cu_1 and M_3, the complete loss of one branch in *Trichoptilus,* and the complete or partial loss, by independent reduction, of the remaining branch in *T. pygmaeus* Wlsm.

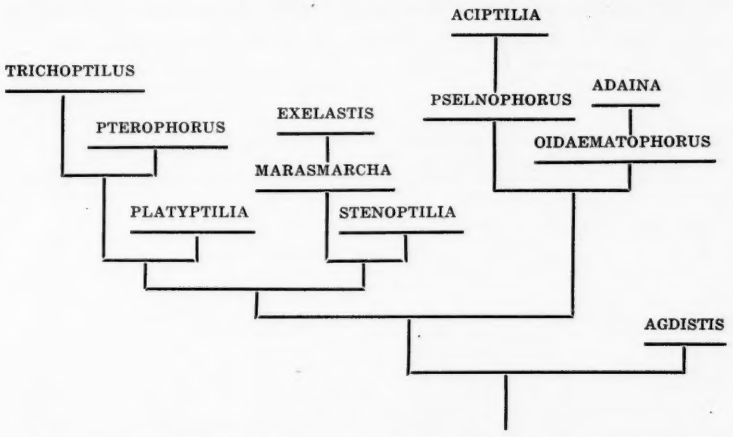
The radius of the primaries is the one other vein whose history is complex. The fact that its fifth branch runs to the apex of the wing in *Agdistis* but ends behind the apex in all of the cleft-winged genera where it is indubitably present, suggests fundamental separation of these lines, as has long been the writer's view. A significant fact regarding this vein is that no genus retaining five branches of the radius has the fifth stalked with another, although the third and fourth are frequently stalked, (and the second with them in some specimens of *Pselnophorus belfragei* Fish, with only four branches remaining). In the genera retaining only four branches of the radius, several things may be noted. First, when the posterior branches are stalked, the most posterior ends in the apex of the wing, both conditions suggesting that it is R_4 or a complex including this vein. Second, when the most posterior branch of the four is not stalked, it ends behind the apex, and excepting *Oidaematophorus,* is preceded by stalked branches, both conditions suggesting that it is R_5. Third, when R_5 as thus interpreted is present, it appears that the progressive anastomosis of R_2, R_3 and R_4, actually visible in a series of *P. belfragei* Fish, has resulted in the coincidence of two branches. These would naturally be the two showing the earliest and most prevalent tendency to unite, viz., R_3 and R_4, and the vein ending in the apex of the primaries must be R_{3+4}. This is a condition such as seen in the wings of *Pterophorus periscelidactylus* Fitch. (Fig. 2)

In *T. pygmaeus* Wlsm. three radial branches at the most are present, and the first two show partial reduction without stalking. Apparently then both R_1 and R_2 may be lost in this way. The writer's previous association of the genus, phylogenetically, with *Pterophorus (Oxyptilus)* cannot stand, since in the latter R_2 is invariably stalked. Meyrick's diagnosis of *Trichoptilus* states, however, that R_2 may be stalked. This would indicate that some of the exotic species, not available to the writer for examination, represent a different line of evolution which may properly be derived from *Pterophorus (Oxyptilus).*

The condition of the veins in some of the more specialized genera, of which *Aciptilia* is the most extreme, is one which can-

not be satisfactorily interpreted without studies of the tracheation of pupal wings. The single vein in the first lobe of the primaries of this genus may be R_{2+3+4}, with R_1 independently lost, or R_{3+4} with both R_1 and R_2 independently lost.

This interpretation of neuration together with the characters found in other parts of the body modifies the writer's former opinions of the phylogeny of the North American genera as expressed in the Pterophoridae of America (Diagram, p. 286). In addition to actual differences between existing genera, it now seems unlikely that so many of these genera represent the ancestry of others. Rather than this, they seem to be derived from common ancestors in most cases. The following diagram expresses the writer's modified view of the phylogeny of our genera.



In order to correct the inaccuracies which crept into the key to North American genera in the Pterophoridae of America, the following key has been prepared. It has been found impossible to construct a key without falling back on neuration at some point, therefore it has been used freely to produce an accurate key. The wings may easily be examined as transparent objects without denuding or bleaching if they are mounted in pure alcohol on a microscope slide, and all veins and thickened lines then become visible.

KEY TO THE NORTH AMERICAN GENERA OF PTEROPHORIDAE

1. Wings entire ..... *Agdistis*
   Wings cleft 2
2. Radius of primaries with four branches or less 3
   Radius of primaries with five branches 10
3. Primaries with only one or two veins in second lobe, anals excepted; deeply cleft, with slender lobes 4
   With M_3, Cu_1 and Cu_2 all present 5
4. Two or three branches of radius present ..... *Trichoptilus*
   Only one radial ..... *Aciptilia*
5. Primaries with all branches of radius free ..... *Oidaematophorus*
   Some branches stalked 6
6. With a free vein (R_5) behind the stalked branches of the radius, ending behind apex of first lobe 7
   The last branches of the radius stalked ..... *Pselnophorus*
7. Secondaries with a tuft of black scales near tip of third feather ..... *Pterophorus*
   No such tuft 8
8. Second lobe of secondaries with two veins ..... *Adaina*
   With three veins 9
9. Fringes of inner margin of third lobe of secondaries with a few scales, sometimes faint in our species ..... *Exelastis*
   Without such scales ..... *Marasmarcha*
10. R_2, R_3 and R_4 stalked ..... *Pterophorus*
    R_3 and R_4 alone stalked 11
11. Secondaries usually with black scales in fringes of inner margin. Anal angles of both lobes of primaries usually prominent ..... *Platyptilia*
    Without black scales. Anal angles present but retreating ..... *Stenoptilia*

PLATE XX

Neuration of Pterophoridae.

1. *Trichoptilus lobidactylus* Fitch.
2. *Pterophorus periscelidactylus* Fitch.
3. *Platyptilia carduidactyla* Riley.
4. *Pselnophorus belfragei* Fish.
5. *Adaina zephyria* B. & L.
6. *Aciptilia walsinghami* Fern.
7. *Oidaematophorus lithodactylus* Tr.

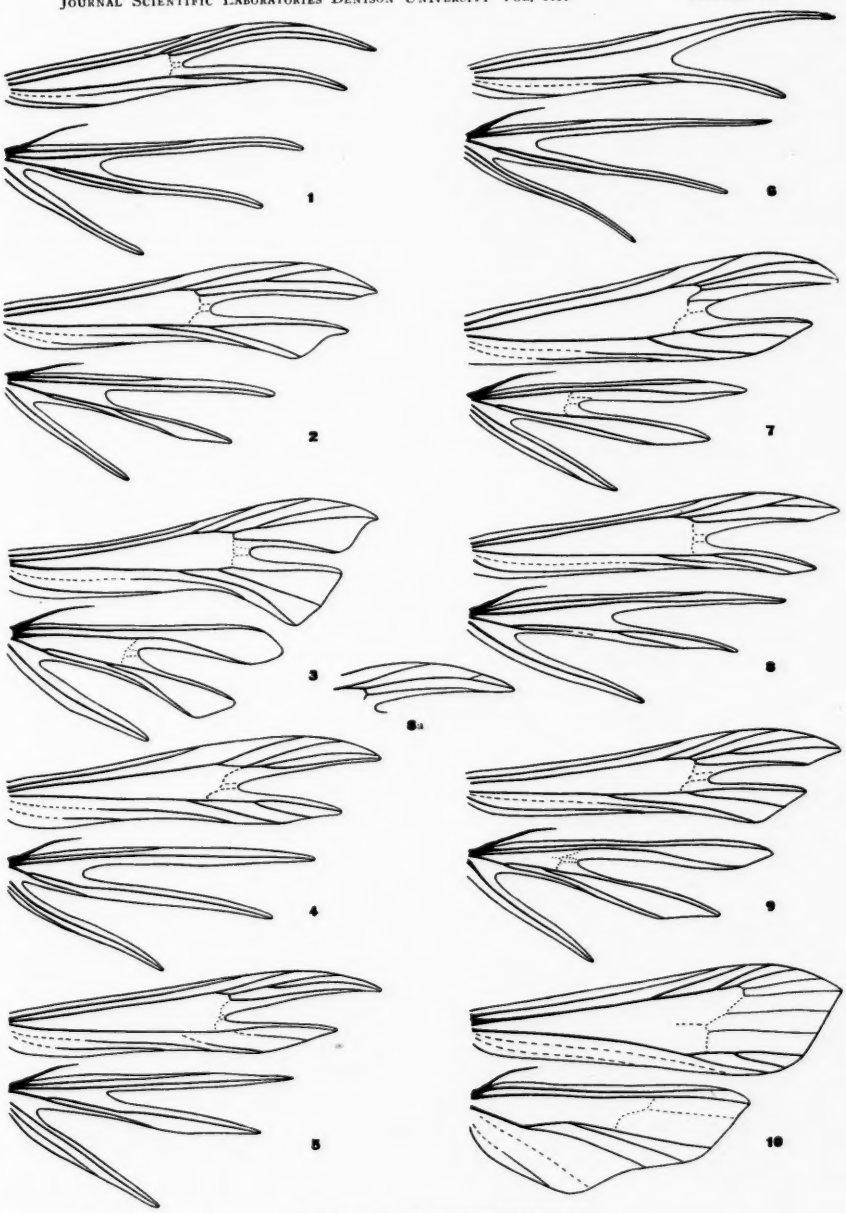
(Genotype, European)

8. *Marasmarcha pumilio* Zell.

8a. *Exelastis cervinicolor* B. & McD.

(First lobe of primary)

9. *Stenoptilia pterodactyla* Linn. (Genotype).
10. *Agdistis americana* B. & L.



A. W. LINDSEY NEURATION OF PTEROPHORIDAE

NOTES ON AMERICAN PALEOZOIC CEPHALOPODS

AUG. F. FOERSTE

INTRODUCTION

The writer has been engaged for a number of years on an intensive study of Ordovician and Silurian cephalopods with special reference to those of American origin. The study is far from complete. A large quantity of the available material has not yet been examined, and some of that already studied must be re-examined in the light of later observations. Research of this sort is greatly expedited by the helpful criticism of others interested in the same field; but in the absence of published reports of progress, such assistance is limited to that secured at occasional meetings. Moreover, it is desirable to reduce to printed form some of the results thus far obtained, in order that they may be available for use in other studies. The following notes are accordingly a miscellaneous gathering, in part intended to invite criticism, and in part intended to report progress, especially along the line of generic relations.

The conclusion has been reached that Ozarkian and Canadian cephalopods were largely holochoanitic in structure and that the first ellipochoanoidal cephalopods were of Chazyan age. In holochoanoidal cephalopods the septal necks extend downward so that each is in contact with the upper margin of the neck beneath, into which it invaginates without connecting ring or sheath. The septal necks of ellipochoanoidal cephalopods are short, and successive necks are connected by ring-like segments, called connecting rings or sheaths. Frequently these connecting rings have failed of preservation and then only the unconnected septal necks may be seen. In other specimens, especially those of Actinoceroids, the septa likewise are wanting, but the siphuncle remains, reinforced by interior calcareous deposits.

Certain species of cephalopods almost or quite invariably lack all trace of connecting rings. Probably in these species the membrane which ordinarily secreted the calcareous material either formed only a very thin deposit or none at all.

Such holochoanitic genera as *Endoceras, Cameroceras* and *Piloceras* have siphuncles built by successive septal necks which extend downward until each invaginates into the neck next beneath. Within the camerae this type of neck generally has a concave vertical outline. The septal necks of *Clarkoceras, Eremoceras, Ellesmereoceras* and *Protocycloceras*[1] have vertical outlines similarly concave. Ruedemann has shown corresponding structures in *Protocycloceras, Orygoceras* and *Cyclostomiceras.*[2] A recent examination of all the orthoconic and crytoceraconic species described by Billings from the Canadian, indicates that concave vertical outlines prevail in all the specimens which reveal the structure of the siphuncle. The typical Black River form of *Cyrtocerina* has an ellipochoanoidal structure, but the siphuncle of the Canadian species *Cyrtocerina mercurius,* presents segments with concave vertical outlines, thus indicating that it is really a *Clarkoceras.* In the numerous species of *"Orthoceras"* described by Billings, concave vertical outlines prevail along the segments of the siphuncle within the camerae.

Apparently the structure of the Canadian orthocones and cyrtoceracones is prevailingly that of the holochoanitic cephalopods. Corresponding ellipochoanoidal genera make their appearance in Chazyan time, though such holochoanoidal genera as *Endoceras* continue through that epoch into later stages. If these observations are verified by increasing knowledge of Ozarkian and Canadian cephalopods, they would suggest that the interval between the Canadian and Chazyan stages was one of the most important in geologic history, sufficient to admit of a major change in the structure of cephalopods. If corresponding changes are found in other groups of animals, contrasting those of Canadian age with those of Chazyan and later times, the separation of Canadian strata from the Ordovician system would seem as fully warranted by paleontology as by stratigraphy.

The enormous number and variety of species which have been referred to the genus *Orthoceras* has always been a serious problem to the systematist. Barrande grouped his numerous species into various divisions based on surface ornamentations. Hyatt has proposed generic names for the major groups. Later, Hyatt

[1] Foerste, A. F., Notes on Arctic Ordovician and Silurian cephalopods; Journ. Sci. Lab. Denison Univ., vol. 19, pp. 261-271, 1921.

[2] Ruedemann, R., Cephalopoda of the Beekmantown and Chazy formations of the Champlain basin; New York State Museum Bull. 90, pp. 444, 451, 502, 1906.

attempted in Zittel-Eastman's Text-book of Paleontology to introduce diagnostic characters based on internal structure, but apparently without any considerable degree of success.

Although the generic names introduced by Hyatt have proved very convenient in the past, it is now evident that dissimilar groups are in some cases included under a single generic heading, so that it is probable that further subdivision of this genus is desirable. Before this is done, however, the types of the genera previously proposed must be studied with the view of determining the proper limits to assign to those genera in restricting or subdividing them. Here there are several difficulties. It is practically impossible to determine what species forms the real type of *Orthoceras*, nor is the interpretation of *Cycloceras* clear. Moreover, the genera *Geisonoceras*, *Dawsonoceras* and *Spyroceras*, proposed by Hyatt, must be interpreted from the original type species and not as redefined by Hyatt in the Zittel-Eastman Textbook.

Similar statements apply to the different subdivisions which have been proposed for the genus *Actinoceras*. The name *Sactoceras*, established with a Silurian species for its type, should probably not be discarded for *Loxoceras*, based on a Carboniferous species.

Looking toward a clearer understanding of these cephalopods, the new genus, *Perigrammoceras*, is here proposed to accommodate certain orthoceroids, and a new subdivision of *Actinoceras* is given the generic name, *Elrodoceras*. The familiar species *Trochoceras* (?) *baeri* is made the type of another new genus, *Charactoceras*.

The many species ordinarily assigned to the genus *Oncoceras* are apparently divisible into two groups, one of which is typified by *O. pandion* Hall, while the other is the true *Oncoceras* with *O. constrictum* Hall as its type. For the *O. pandion* group the name *Beloitoceras* is proposed. It was apparently from *Beloitoceras* that *Maelonoceras* was evolved. Either *Beloitoceras* should be considered an independent genus or it should be made a subdivision of *Maelonoceras*. But if the second alternative is chosen, *Maelonoceras* must be used in a broader sense than the customary interpretation based on the genotype, *M. praematurum*.

Another group of conchs, sometimes included in *Oncoceras*, is typified by the species originally described as *Cyrtoceras orcas*

Hall. *C. laterale* and *C. orodes* are closely similar species. For these the term *Amphicyrtoceras* is proposed. Among other forms having about the same characteristics are *Oncoceras futile* Billings, *O. pettiti* Billings and *O. teucer* Billings. *Streptoceras* differs from *Amphicyrtoceras* chiefly in the more triangular outline of the aperture due to the anterior extension of the hyponomic sinus into a sort of lip. It probably was derived from the latter genus. *Poterioceras* is unknown in Silurian strata.

Among gomphoceroid conchs, there is a primitive group, known to be represented in the Richmond and probably present also in earlier strata, which has only a moderate angulation at the hyponomic sinus instead of a strong constriction as in typical *Gomphoceras*. For this group the term *Diestoceras* is proposed, with *G. indianense* as the genotype. This genus also includes *G. obesum* Billings and *G. eos* Hall and Whitfield.

Finally, the generic terms *Westonoceras* and *Cyrtogomphoceras* are here proposed for the very aberrant species, *Cyrtoceras manitobense* Whiteaves and *Oncoceras magnum* Whiteaves.

ACKNOWLEDGEMENTS

It is needless to state that it would have been impossible to carry on the studies included in the present publication if it had not been for the good will and generous helpfulness shown by many individuals. I am especially indebted to Dr. R. S. Bassler of the U. S. National Museum; Dr. E. M. Kindle of the Victoria Memorial Museum; Prof. Percy Raymond and Mr. Samuel Henshaw of Harvard University; Dr. Chester A. Reeds and Dr. E. O. Hovey of the American Museum of Natural History; Prof. J. E. Carman of Ohio State University; Prof. Stuart Weller and Mr. Arthur W. Slocom of the University of Chicago; Mr. Henry L. Ward of the Public Museum of Milwaukee; Prof. W. H. Shideler of Miami University; Mr. C. L. Faber of Cincinnati, and Judge Henry Pavey, now deceased, of Hillsboro, Ohio. Without assistance from these individuals, and the loan of specimens from collections under their care, little of permanent value could have been accomplished.

I am under special obligations to Dr. David White and Mr. Walter C. Mendenhall, of the U. S. Geological Survey, for access to the facilities of that Survey, and for giving me every encouragement.

1. THE HOLOCHOANITIC CEPHALOPODS OF CANADIAN STRATA

Ulrich included in the Canadian series of strata the Beekmantown of New York, Vermont, and adjacent Canada, the Levis of the Quebec area, the Romaine of the Mingan island area, all but the basal part of the Bretonian of Nova Scotia, the upper part of the Quebec group of Newfoundland, and the approximate equivalent of these strata elsewhere. Those strata which intervene between the Canadian and the typical Cambrian he included in the Ozarkian. The fauna of the Potsdam standstone is regarded as distinct from the typical Cambrian and as characterizing the basal part of the Ozarkian.

The cephalopod fauna of the Ozarkian and Canadian differs so strongly from that of the overlying Ordovician that it suggests that the interval between the Canadian and the Ordovician is one of the great time-breaks of geology. Very few genera bridge the interval between the Canadian and Ordovician, and these few are represented in the Ordovician by species which usually are strikingly different from those in the Canadian.

Such genera as *Eurystomites, Tarphyceras, Aphetoceras* and *Trocholitoceras* are, strictly speaking, Canadian. It is possible that an intensive study of *Eurystomites plicatus* and *Eurystomites robertsoni* will reveal differences from the typical Canadian forms of sufficient importance to be at least of subgeneric rank. In *Eurystomites plicatus,* for instance, the segments of the siphuncle enlarge slightly within the camerae, as though short septal necks with intermediate connecting rings were present, while this appearance is not noted in Canadian species. In *Tarphyceras multicameratum,* moreover, the camerae are much shallower and the rate of increase in diameter of the conch is greater. Nothing corresponding to the Canadian species of *Schroederoceras* occurs in the Ordovician of North America. Typical *Schroederoceras,* of course, is European, 8 European species being recognized by Hyatt. Typical *Trocholites* is of Trenton or Cincinnatian age, but *Trocholites internistriatus* (Whitfield) occurs as early as the Beekmantown division of the Canadian.

The Canadian species described by Ruedemann under the term *Cyrtendoceras* (?) *priscum* differs from anything known in the Ordovician of America.

Canadian as well as Ordovician and Silurian species have been

referred to the genera *Cyclostomiceras*, *Cyrtocerina*, and *Maelonoceras*, but the Canadian species so referred belong to different genera from those occurring in later strata. In typical *Cyclostomiceras*, of Canadian age, the segments of the siphuncle present concave vertical outlines, while the Niagaran species *Cyrtoeras brevicorne* Hall and *Cyrtoceras orodes* Billings, referred by Grabau and Shimer to *Cyclostomiceras*, belong to a distinct genus with short septal necks and convex connecting rings, for which the term *Amphicyrtoceras* is proposed on the following pages. *Cyrtocerina typica* Billings, from the Black River, has nummuloidal segments in the siphuncle (Plate XLI, Fig. 9) while in *Cyrtocerina mercurius* Billings these segments present concave vertical outlines (Plate XLI, Fig. 8) as in *Clarkoceras*, a genus which seems to be confined to the Canadian. In *Maelonoceras praematurum* (Billings), from the Black River, the segments of the siphuncle are subfusiform, while in *Cyrtoceras metellus* Billings, from the Canadian, these segments are strongly nummuloidal in form, if specimen No. 820a in the Victoria Memorial Museum correctly represents this species.

Such genera as *Eremoceras* and *Piloceras* are confined to the Canadian. In both, the segments of the siphuncle have concave vertical outlines within the camerae.

Concave vertical outlines are presented also by a considerable number of those orthoconic shells which were described by Billings and others from Canadian strata under the generic term *Orthoceras*. In fact, all of the Canadian orthoconic species, concerning which it has been possible to learn the structure of the siphuncle, have siphuncular segments with concave vertical outlines. Of these, the annulated forms are, at present, referred to *Protocycloceras*. Possibly most of the smooth forms will fall under *Ellesmereoceras*.[3] They are characterized, as a rule, by rather closely arranged septa and by siphuncles of more moderate size than in typical *Endoceras*. Orthoconic specimens, with siphuncles more readily comparable with those of typical *Endoceras*, also exist in Canadian strata. In none of the Canadian Endoceroid specimens described by Billings has it been possible to discover the presence of endocones. From this it does not follow necessarily that endocones are absent, since the actual

[3] Foerste, A. F., Notes on Arctic Ordovician and Silurian cephalopods; Journ. Sci. Lab. Denison Univ., vol. 19, p. 265, pl. 27, figs. 3A, B, C; pl. 33, fig. 3, 1921.

number of specimens which expose well the interior of the siphuncle is relatively small. However, when the genus *Ellesmereoceras* was described, the absence of endocones was regarded as one of its characteristic features.

Orygoceras is another orthoconic Canadian genus with siphuncular segments presenting concave vertical outlines. The conch displays a smooth exterior, but an annulated interior.

Canadian cephalopods are remarkable for the number of genera and species in which the segments of the siphuncle present concave vertical outlines. Such outlines are characteristic of the holochoanitic cephalopods, in which the septal necks are prolonged downward at least the height of one of the camerae.

In Zittel-Eastman's Text-book of Paleontology the Holochoanites include the genera *Vaginoceras, Cameroceras, Endoceras, Narthecoceras, Nanno, Piloceras,* and *Cyrtendoceras.* To this list the genera *Cyclendoceras* and *Clarkoceras* have been added by Bassler.[4] Ruedemann recognized the holochoanitic structure of the siphuncle of *Protocycloceras,*[5] his illustrations show the concave vertical outlines of the siphuncular segments of *Cyclostomiceras.* His vertical section of *Orygoceras* indicates a similar structure. The present writer has described the concave vertical outlines of the siphuncular segments of *Eremoceras* and *Ellesmereoceras,* and in the present bulletin he calls attention to similar structure in various orthoconic cephalopods described by Billings from Canadian strata.

Although it does not follow necessarily that species with siphuncular segments having concave vertical outlines are holochoanoidal in structure, the writer believes that such a relationship exits. Should this prove to be true, after further investigation, then it follows that the chief characteristic of Canadian orthoconic and cyrtoconic cephalopods is the remarkable dominance of holochoanitic forms.

Although such holochoanitic genera as *Cameroceras, Cyclendoceras, Endoceras, Narthecoceras, Nanno, Suecoceras,* and *Vaginoceras* are well represented in Ordovician strata, they here are associated with numerous Orthochoanitic and Cyrtochoanitic forms which are either rare or absent in Canadian strata. The

[4] Bassler, R. S., Bibliographic Index of American Ordovician and Silurian fossils; U. S. Nat. Museum Bull. 92, 1915.

[5] Ruedemann, R., Cephalopoda of the Beekmantown and Chazy formations of the Champlain basin; New York State Museum Bull. 90, p. 441, 1906.

Canadian, in brief, is characterized by the dominance of holochoanitic cephalopods, and the early Ordovician by the influx of numerous Orthochoanitic and Cyrtochoanitic cephalopods.

It should be noted that in some of the Canadian genera of cephalopods, here cited as having concave vertical outlines, this concavity is so faint that their outlines are described more readily as straight than concave; but they are distinctly not convex. This is true, for instance, of the species originally described as *Cyrtoceras quebecense*.

2. SMOOTH ORTHOCONIC CANADIAN CEPHALOPODS

Most of the smooth orthoconic cephalopods found in the Canadian strata in Canada have the siphuncle in contact with the ventral wall of the conch. The sutures of the septa of *Orthoceras sordidum* Billings curve downward distinctly on the ventral side of the conch, as in the specimen figured by Ruedemann[6] from Fort Cassin, Vermont, under the name *Endoceras montrealense*. The septal necks extend downward the length of one camera and present a concave vertical outline within the camerae. Similar septal necks are found in *Orthoceras montrealense* Billings and *Orthoceras glaucum* Billings. These species are alike in the small height of their camerae. In this respect they resemble *Ellesmereoceras scheii* Foerste, to which they may be closely related.

In *Orthoceras indagator* Billings the structure of the siphuncle is more like that of typical *Endoceras*. While the general vertical outline of the septal necks is concave within the camerae, the lower end of these necks curves inward to invaginate within the upper part of the neck next beneath. The upper part of the siphuncle of one specimen, numbered 7454 in the Victoria Memorial Museum, appears to contain an endocone. Apparently *Orthoceras indagator* is one of the earliest known forms of typical *Endoceras*, a genus common in the Chazyan.

Nothing is known of the structure of the septal necks in *Orthoceras sayi*, *O. autolycus*, *O. veterator* or *O. perseus*, all described by Billings from Canadian strata, with the possibility of *O. autolycus* having been derived from Ozarkian strata, since it occurs in conglomeratic layers. Of these species, *Orthoceras sayi* has such a large siphuncle that it resembles typical *Endoceras* in

[6] Ruedemann, R., op. cit., p. 424.

transverse sections. In the other three species the siphuncles are relatively smaller and the camerae are closely crowded, as in *Ellesmereoceras*. It will require vertical sections of the types to determine their affinity with any confidence.

The siphuncle of *Orthoceras atticus*, *O. becki* and *O. explorator*, all described by Billings from Canadian strata, is not in contact with the ventral wall of the conch, but is between the ventral wall and the center. The siphuncle of *O. atticus* was described by Billings as "not much, if at all, inflated between the septa." That of *O. explorator* is described as cylindrical. In none of the three species is the structure of the siphuncle known with sufficient accuracy to determine whether it belongs to the group with long septal necks, as in the Endoceroids, or to the group with short septal necks, as in the Orthoceroids.

So far, no orthoconic cephalopods have been found in Canadian strata of which it is known with certainty that they belong to the Orthoceratida rather than to the Endoceratida. On this account it would be desirable to investigate all known Canadian orthoconic species with the object of determining the structure of their siphuncles. It is evident that if typical Orthoceratida should prove absent in Canadian and Ozarkian strata, this fact would be of great service in identifying the horizon of some of the lower Paleozoic formations.

The single specimen of *Orthoceras primigenium*, figured by Hall[7] from the Canadian near Fort Plain in the Mohawk valley of New York, has a conch estimated to have been about 18 or 19 mm. in diameter at its lower end, enlarging possibly to 22 mm. at its upper end. A thickness of only 2 to 3 mm. of one side of the conch remains. There is no trace of annulation of the surface of the shell. The specimen consists of a living chamber 14 mm. in height above the suture of the uppermost septum. On the left margin of the specimen 12 camerae occur in a length of 9 mm. The two uppermost camerae are distinctly shallower than those beneath, suggesting that the conch had reached full maturity. The concavity of the septa along that part of the specimen which is preserved equals 2 mm.; evidently toward the center of the original specimen this concavity must have been much greater. There the specimen in its present condition is 13 mm. in width, the maximum concavity is 4.5 mm. from the left side, and the

[7] Hall, J., Pal. New York, vol. 1, 1847, pl. 3, fig. 11.

septa rise 2.5 mm. higher on the right side than on the left. This indicates that the sutures of the septa are oblique, and that the siphuncle probably was located nearer the left side of the specimen, somewhere in that part which has weathered away. On the right side of the specimen the septa are more closely crowded, suggesting that, notwithstanding the general orthoconic aspect of the specimen, it may have been somewhat cyrtoconic in structure. There is no evidence that this single specimen is even congeneric with the small apical ends of orthoconic shells figured by Hall on the same plate (Fig. 11a).

3. ELLESMEREOCERAS FOERSTE

Genotype: **Ellesmereoceras scheii** Foerste. Journ. Sci. Lab., Denison Univ., vol. 19, p. 265, pl. 27, figs. 3 A, B, C.; pl. 33, fig. 3, 1921

The genus *Ellesmereoceras* was founded on the belief that there was a group of Endoceroids in which endocones were absent. If eventually it should be proved that endocones were present, the value of this generic term would be questionable. In most of the species having the general appearance of *Ellesmereoceras* the vertical outlines of the septal necks are distinctly concave, but there is no clear evidence of the invagination of the lower part of these necks into the upper part of the neck next beneath, as in typical *Endoceras*. The camerae usually are closely crowded.

This type of structure appears to be characteristic of Canadian strata, but may have originated in Ozarkian times.

Holochoanitic cephalopods with endocones are known to be present in the Ozarkian, and are under investigation by Dr. E. O. Ulrich.

4. PROTOCYCLOCERAS HYATT

Genotype: **Orthoceras lamarcki** Billings. Canadian Nat., vol. 4, 1859, p. 362; Foerste, Journ. Sci. Lab. Denison Univ., vol. 19, 1921, p. 268, pl. 33, figs. 7 A-D

Protocycloceras was established by Hyatt to include annulated orthoceracones and cyrtoceracones without longitudinal ridges but with a large siphuncle.

Ruedemann has shown[8] that in *Orthoceras lamarcki*, the genotype, the septal necks have a length equal to that of one camera, and that within the camerae their vertical outlines are concave. He has also figured a similar structure in *Protocycloceras whit-*

[8] Ruedemann, R., op. cit., p. 440.

fieldi Ruedemann.[9] *Orthoceras ordinatum* Billings likewise possesses septal necks with concave vertical outlines within the camerae. In the three species here named the siphuncle is not in contact with the ventral wall of the conch. In all the other annulated orthoconic species described by Billings from Canadian strata, contact of the siphuncle with the ventral wall of the conch prevails.

Nothing is known about the siphuncle of *Orthoceras catulus*, *O. furtivum*, and *O. repens*, beyond the fact that its general form is cylindrical, and that it is in contact with the ventral wall of the conch. All are Canadian species, described by Billings.

In *Orthoceras cataline*, *O. xerxes*, and *O. cato*, also described by Billings from Canadian strata, the conchs are not only annulated but also striated transversely. In all three of these species the septal necks are distinctly concave within the camerae. Transverse striae were not discovered on any of the other Canadian annulated orthocones mentioned in the preceding paragraphs.

In *Orthoceras henrietta* Dwight the conch is strongly annulated. The siphuncle is nearly in contact with the ventral wall and is 1 mm. in diameter where the diameter of the conch is 6.4 mm.

Apparently all of the above species are to be included in *Protocycloceras*.

5. ORYGOCERAS RUEDEMANN

Genotype: **Orthoceras cornuoryx** Whitfield. Amer. Mus. Nat. Hist. Bull., 1, 1886, p. 320, pl. 27, figs. 1, 2, 6; Ruedemann, New York State Mus. Bull., 90, 1906, p. 450, pl. 14, figs. 5-8, text fig. 19, 20

Orygoceras is described as consisting of conchs which are smooth externally but which internally are annulated. The siphuncle is small and is almost 1 mm. from the ventral wall of the conch. Ruedemann describes the siphuncle as orthochoanitic, the septal necks being short and straight and the remainder of the siphuncle being formed by the intervening connecting sheaths. In his figure,[10] the vertical outline of the segments of the siphuncle included within successive camerae is seen to have been concave. His section passes through the center of the siphuncle in a lateral direction.

[9] Idem, p. 444, figs. 17a, b.
[10] Idem, p. 451. fig. 20.

6. CLARKOCERAS RUEDEMANN

Genotype: **Piloceras newton-winchelli** Clarke. Geol. Minnesota, vol. 3, pt. 2, 1897, p. 767, figs. 8, 9; pl. 47, figs. 1-3. Ruedemann, New York State Mus. Bull., 80, 1905, p. 337

Clarkoceras proclaims its relationship to the suborder *Holochoanites* not only by the presence of endocones but also by the concave outline of the segments of the siphuncle within the camerae. The septal necks apparently extend the length of one camera. Excellent figures of the structure of the genotype are presented by Clarke. The siphuncle is free from contact with the adjacent wall of the conch.

Clarkoceras holtedahli Foerste,[11] from the Canadian of Bache peninsula on Ellesmereland, evidently is congeneric. Here also, the elongated septal necks present concave vertical outlines within the camerae, as in *Piloceras*. The siphuncle is almost in contact with the adjacent wall of the conch.

A similar structure is displayed by the species *Cyrtocerina mercurius* Billings (Plate XLI, Fig. 8), described from the Canadian at Point Lewis, opposite Quebec. This species is related to, but is not congeneric with *Clarkoceras*.

Typical *Cyrtocerina* (Plate XLI, Fig. 9), however, as represented by its genotype *Cyrtocerina typica* Billings, from the Black River (Leray) at Pauquette Rapids, Ottawa river, Canada, belongs to the group *Ellipochoanida*, as originally defined by Hyatt.[12] This group included both the suborder *Orthochoanites* and *Cyrtochoanites* as defined later in Zittel-Eastman's Textbook of Paleontology. Judging from the convex curvature of the segments of the siphuncle within the camerae, the relationship of typical *Cyrtocerina* is with the *Cyrtochoanites*.

Among the various species described by Billings from the Canadian strata of Canada under the name Orthoceras, there are two which evidently are related to *Clarkoceras*, although their degree of relationship can not be determined until the conch, as a whole, is known. These species are *Orthoceras missiquoi* and *Orthoceras edax*.

In *Orthoceras missiquoi* the siphuncles are slightly curved, especially toward the apical end. That side of the siphuncle which is concavely curved lengthwise is smooth and a little flat-

[11] Foerste, A. F., op. cit., pl. 27, figs. 2A, B; pl. 33, fig. 1.

[12] Hyatt, A., Genera of fossil cephalopods; Boston Soc. Nat. Hist., Proc., vol. 22, p. 260, 1883.

tened and evidently was in contact with the ventral wall of the conch, so that the location of the siphuncle must have been endogastric, as in *Clarkoceras*. Along the remainder of the contour of the siphuncle the septal necks appear to have equalled in length the height of the camerae, and to have presented vertical outlines within these camerae. In one of the specimens an endocone apparently was present. *Orthoceras edax* shows a similar structure. Both *Orthoceras missiquoi* and *O. edax* are congeneric with *Cyrtoceras quebecense* Whiteaves, described from Point Lewis, opposite Quebec. The conch of the latter species is relatively much more elongated than in typical *Clarkoceras;* the segments of the siphuncle are cylindrical in form, and consist of the septal necks, each of which is one camera in length.

7. EREMOCERAS (HYATT) FOERSTE

Genotype: **Cyrtoceras syphax** Billings. Pal. Foss., vol. 1 ,Geol. Surv. Canada, 1865, p. 194, text fig. 178. Foerste, Journ. Sci. Lab. Denison Univ., vol. 19, 1921, p. 263, pl. 33, figs. 8 A, B. C; 2

Eremoceras is a small subfusiform cephalopod, somewhat like *Cyclostomiceras* in form. The dorsal side of the conch is distinctly convex lengthwise, while the ventral side is almost straight. The camerae are closely crowded. The siphuncle is large, and endogastric in location. It is in contact with the ventral side of the conch for the greater part of its width. In the type specimen, the siphuncle is depressed dorso-ventrally, being considerably more convex along the side facing the interior of the conch. Vertical outlines of the septal necks are curved slightly inward within the camerae, as in the Endoceratida. The genus is known only in Canadian strata.

Cyrtoceras aristides Billings may be related to *Eremoceras.* The siphuncle is large and in contact with the adjacent wall of the conch, and the living chamber apparently contracts toward the top. Better specimens than the type are needed for exact reference.

8. CYCLOSTOMICERAS HYATT

Genotype: **Gomphoceras cassinense** Whitfield. Amer. Mus. Nat. Hist. Bull., vol. 1, 1886, p. 322, pl. 29, figs. 1-3. Ruedemann, New York State Mus. Bull., 90, 1906, p. 501, fig. 56; pl. 37, figs. 1-3; pl. 38, figs. 5, 6

Conch subfusiform in outline, the greatest diameter being at or immediately below mid-height of the living chamber. The

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[11] Foerste, A. F., op. cit., pl. 27, figs. 2A, B; pl. 33, fig. 1.

[12] Hyatt, A., Genera of fossil cephalopods; Boston Soc. Nat. Hist., Proc., vol. 22, p. 260, 1883.

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Eremoceras is a small subfusiform cephalopod, somewhat like *Cyclostomiceras* in form. The dorsal side of the conch is distinctly convex lengthwise, while the ventral side is almost straight. The camerae are closely crowded. The siphuncle is large, and endogastric in location. It is in contact with the ventral side of the conch for the greater part of its width. In the type specimen, the siphuncle is depressed dorso-ventrally, being considerably more convex along the side facing the interior of the conch. Vertical outlines of the septal necks are curved slightly inward within the camerae, as in the Endoceratida. The genus is known only in Canadian strata.

Cyrtoceras aristides Billings may be related to *Eremoceras*. The siphuncle is large and in contact with the adjacent wall of the conch, and the living chamber apparently contracts toward the top. Better specimens than the type are needed for exact reference.

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Genotype: **Gomphoceras cassinense** Whitfield. Amer. Mus. Nat. Hist. Bull., vol. 1, 1886, p. 322, pl. 29, figs. 1-3. Ruedemann, New York State Mus. Bull., 90, 1906, p. 501, fig. 56; pl. 37, figs. 1-3; pl. 38, figs. 5, 6

Conch subfusiform in outline, the greatest diameter being at or immediately below mid-height of the living chamber. The

lengthwise curvature of the dorsal side is greater than that of the ventral side, and the siphuncle is close to the ventral side, but not in contact with the latter. In this position the siphuncle is said to be endogastric. The segments of the siphuncle present concave vertical outlines within the camerae, as well illustrated by Ruedemann. The septal funnels curve backward a distance equal to one camera.

Only two species of *Cyclostomiceras* are known: *cassinense* (Whitfield) and *C. minimum* (Whitfield); both are confined to the Canadian (Beekmantown) of Vermont.

The relationship of *Cyrtoceras aristides* Billings, of Canadian age, can not be determined in our present knowledge of that species. The living chamber apparently contracts toward the top somewhat as in a small *Cyclostomiceras*, but the siphuncle is rather large. Although the siphuncle is known to be in contact with the ventral wall of the conch, it is not possible to determine from the type in its present condition, imbedded in the matrix, whether its location is endogastric or exogastric. Nothing is known about the structure of the siphuncle.

9. EXOGASTRIC CYRTOCEROIDS OF CANADIAN AGE

The conch of *Cyrtoceras confertissimum* Whitfield is distinctly curved lengthwise and depressed dorso-ventrally. The siphuncle is near the convexly curved side of the conch. According to Ruedemann[13] the septal necks are short and the siphuncular segments are nearly tubular, but very slightly contracted within the camerae. This concave outline of the siphuncular segments is characteristic of the numerous species referred to *Orthoceras*, by Billings and other authors, in Canadian strata. The dorso-ventral depression of the conch, however, is a feature not seen in these so-called Orthoceroids.

In *Cyrtoceras alethes* Billings, which may be of Ozarkian rather than of Canadian age, the conch is moderately curved lengthwise and strongly compressed laterally. The ventral side has a radius of lengthwise curvature of 25 mm. and a radius of lateral curvature of 3 mm. Only 6 camerae are present. If the lengthwise curvature of the ventral side continued along the living chamber the latter would be contracted dorso-ventrally, somewhat as in the species described by Billings from the Black

[13] Ruedemann, R., Cephalopoda of the Beekmantown and Chazy formations of the Champlain basin; New York State Museum Bull. 90, p. 507, 1906.

River of St. Joseph Island under the name *Cyrtoceras huronense*. However, too little of the living chamber is present to determine this with certainty. The siphuncle is in contact with that side of the conch which is curved convexly lengthwise. Its segments may be subfusiform in outline, but not enough is exposed to give a good idea of its structure. The general resemblance of *Cyrtoceras alethes* to such forms as *Cyrtoceras huronense* Billings, C. *isodorus* Billings, C. *pandion* Hall and C. *plebium* is sufficiently great to make it desirable to determine with accuracy whether such an early origin of cyrtoceroids of this type actually took place.

The conch of *Cyrtoceras metellus* Billings is distinctly curved lengthwise and the section is stated to be circular or nearly so. The siphuncle of the type is said to be unknown. Billings stated that this species resembled *Cyrtoceras syphax* Billings very closely; in that case its siphuncle should be located on that side of the conch which is curved concavely lengthwise. However, in the collections of the Geological Survey of Canada, Specimen No. 820a, labelled *Cyrtoceras metellus*, has the siphuncle in contact with the convexly curved side of the conch. The segments are strongly nummuloidal, and, owing to the concavity of the septa, are strongly oblique to the ventral outline of the conch. Moreover, on this specimen the septa rise much higher on the concavely curved side of the conch than on the convex side.

The conch of *Cyrtoceras dictys* Billings is distinctly curved lengthwise and compressed laterally. The species appears related to Specimen 820a, mentioned in the preceding lines, but nothing is known of its siphuncle.

The siphuncle of *Cyrtoceras kirbyi* Whitfield is in contact with the ventral wall of the conch, is 2 mm. in diameter, and its segments appear tubular, constricting slightly along the upper part of the camerae, widening slightly along their lower part, and constricting again where entering the top of the septal neck next beneath. *Cyrtoceras beekmanense* Whitfield appears closely related to *kirbyi*.

In *Cyrtoceras raei* Whitfield, the siphuncle is in contact with the ventral wall of the conch, is 2 mm. in diameter, and its segments appear tubular. Possibly the conch was gyroceran in form, the whorls being depressed dorsoventrally.

In *Cyrtoceras vassarina* Dwight, the conch is laterally com-

pressed, the siphuncle is exogastric, and the vertical outlines of its segments within the camerae are concave.

It is evident that our knowledge of the cyrtoceroids of the Canadian formations is very unsatisfactory. Of course, they would no longer be placed under the genus *Cyrtoceras*, as that genus is restricted at present. *Cyrtoceras metellus* Billings was referred by Hyatt[14] to his genus *Maelonoceras*, but the siphuncle segments of the latter are subfusiform, while those of Specimen No. 820a are strongly nummuloidal.

10. ENDOCERAS HALL

First described species: **Endoceras subcentrale** Hall, from the Black River (Watertown) at Watertown, New York. Pal. New York, vol. 1, 1847, p. 57.

Accepted genotype: **Endoceras proteiforme** Hall. Pal. New York, vol. 1, 1847, p. 208

Endoceras belongs to the group of genera in which the septal necks extend posteriorly until in contact with the septum next beneath. It is distinguished from other genera by the presence of long endocones which taper downward gradually to a point. The sides of these endocones are not in contact with the walls of the siphuncle but are free along their entire length. In typical *Endoceras* the endocones are few and distant from each other. Those species in which the endocones are numerous have been placed by Hyatt in his genus *Vaginoceras*.

In distinguishing *Vaginoceras* from *Endoceras*, Hyatt stated[15] that in *Endoceras* the septal necks extend posteriorly from one septum only as far as the septum next beneath, while in *Vaginoceras* the septal necks extend beyond the next lower septum. It would require a monographic study to determine to what extent either the presence of numerous endocones or the long backward extention of the septal necks might be regarded as of generic value. It is still more doubtful if it is possible to distinguish a genus *(Vaginoceras)* in which the septal necks are more than one camera in length, and in which the endocones are numerous, from another genus *(Endoceras)* in which the septal necks are only one camera in length and in which the endocones are relatively few. Apparently, if *Vaginoceras* is to stand, its validity must be based upon one of these criteria alone, and not on both. The one here selected is the presence of numerous endocones, since *Endoceras multitabulatum* Hall is the genotype of *Vaginoceras*.

[14] Hyatt, A., op. cit., p. 280.
[15] Idem, p. 266.

The first species described by Hall under *Endoceras* is *subcentrale* Hall from the Black River (Watertown) at Watertown, New York. The type specimen of this species is numbered 603 in the American Museum of Natural History. The figure presented by Hall[16] shows only the middle half of the specimen and is printed in an inverted position, with the apical end directed upward. Liberties were taken in the preparation of this figure. An endocone is present, as in the figure, but the septal necks appear to extend posteriorly for a distance of two camerae, the lower half of each septal neck invaginating into the upper half of that next beneath. If emphasis be placed on the lack of numerous endocones, then *Endoceras subcentrale* is as typical an example of *Endoceras* as *proteiforme* Hall, the genotype accepted by Bassler.[17] If emphasis be placed on the elongation of the septal necks, then it agrees in this respect with typical *Vaginoceras*. The present writer regards it as an *Endoceras*.

The second and third species described by Hall under *Endoceras*, namely *longissimum* and *multitabulatum*, belong to Hyatt's genus *Vaginoceras*. The fourth species, *gemelliparum*, appears to be a typical *Endoceras*. The fifth species is the genotype of a new genus, *Cyclendoceras*, established by Grabau and Shimer. The sixth species, *proteiforme*, is accepted by Bassler as the genotype of *Endoceras*, since this is the species best known, and represented by the greatest number of specimens.

In describing *Endoceras proteiforme*, Hall discriminated five varieties, namely *tenuistriatum*, *tenuitextum*, *lineolatum*, *strangulatum* and *elongatum*. Of these, *tenuistriatum*, *tenuitextum*, and *lineolatum* are referred by various authors to *Orthoceras*. The variety *strangulatum* is another Orthoceroid. Only *elongatum* remains as a probable Endoceroid.

Typical *Endoceras proteiforme* Hall is represented by the figures on Plates 48, 49, 50, 53 and 57. The original of Figure 4 on Plate 48 is selected here as the type of the species. The specimens figured on Plate 49 are regarded as cotypes. Owing to the importance of this species in the diagnosis of the genus *Endoceras*, it is described more fully in the following lines.

[16] Hall J., Pal. New York, vol. 1, 1847, pl. 17, fig. 4.

[17] Bassler, R. S., Bibliographic Index of American Ordovician and Silurian fossils; U. S. Nat. Museum Bull. 92, p. 480, 1915.

11. ENDOCERAS PROTEIFORME HALL

PLATE XXI, FIGS. 1-3; PLATE XXII, FIGS. 1-3; PLATE XXIII, FIGS. 1-3; PLATE XXV, FIG. 2

Endoceras proteiforme Hall, Pal. New York, vol. 1, 1847, pl. 48, fig. 4; pl. 49, 1 a-e

Selected type (Plate XXI, Fig. 1; Plate XXII, Figs. 1A, 1B). The original of Figure 4 on Plate 48 of the publication cited above is selected here as the type of the species. This specimen is 120 mm. long. It enlarges from a diameter of 45 mm. at the lowest well defined camera to 51 mm. at a point 100 mm. farther up, or 6 mm. in a length of 100 mm., indicating an apical angle of 3°. The cross-section is approximately circular; possibly there is a little depression dorso-ventrally. The number of camerae in a length equal to the diameter of the conch equals 7 along the entire length of this specimen. The sutures of the septa are directly transverse except along the ventral side of the conch, where they curve more or less distinctly downward on approaching the median part. The septa curve strongly downward, their concavity equaling 9 mm. where the diameter of the specimen is 48 mm. At this point the diameter of the siphuncle is 22 mm. For a width of 10 mm. the siphuncle either is in contact with the ventral wall of the conch or is but very slightly separated from such contact. About 60 mm. farther up, where the diameter of the conch is 52 mm., the diameter of the siphuncle is 30 mm. Immediately above this part of the specimen there is evidence of two endocones, of which the lower one is visible also at the lower point where the diameter of the conch is 48 mm. This lower endocone is estimated to have an apical angle of about 9°. It is evident that the two endocones originated at septa separated by an interval of about 7 camerae, or a length equal to the diameter of the conch. Both endosiphocones lie on the dorsal side of the siphuncle, but this varies in different specimens.

Other Specimens Figured by Hall.—The specimen[18] represented by Figure 1a on Plate 49, accompanying the original description by Hall, has the ventral side of the siphuncle exposed along a width of 18 mm.; apparently the exposed part of the siphuncle originally was in contact with the ventral wall of the conch. The septal necks are faintly concave in vertical sections. Apparently they are only a single camera in length, and

[18] Pl. 21, fig. 2; pl. 22, fig. 2; pl. 23, fig. 2, of this Journal.

their basal part curves outward where joining the top of the septal neck immediately beneath. The apical end of an endosiphocone traverses the greater part of the length of this specimen; it is almost in contact with the ventral wall of the siphuncle. The diameter of the siphuncle is estimated at 30 mm. and that of the conch at 58 mm., but in neither case is more than the ventral side actually exposed. Five camerae occur in a length equal to the diameter of the conch. The apical angle appears to be larger than 3°, but the specimen is not suitable for the accurate measurement of this angle.

The specimen[19] represented by Hall's Figures 1b and 1c on Plate 43 exposes 12 camerae in a length of 106 mm. Near the base of the specimen 7 camerae occur in a length equal to the diameter of the conch; near its upper end 6 camerae occur in a corresponding length. At mid-length the diameter of the specimen is 56 mm. Here the concavity of the septa is 15 mm. The diameter of the siphuncle at the top of the specimen is 26 mm. If the siphuncle was not in actual contact with the ventral wall of the conch, it was at least very close to the latter. About 30 mm. below the top of the specimen an endosiphocone starts downward, and 80 mm. farther down its cross-section is seen at a distance of 1 mm. from contact with the dorsal side of the siphuncle. Here its lateral diameter is 15 mm., and its apical angle is approximately 7° or 8°. The apical angle of the conch probably did not exceed 3°.

Figure 1d on Plate 49 of Hall's monograph represents a specimen with more numerous camerae than usual. The upper end of an endosiphocone is exposed.

Figure 1e on plate 49 represents chiefly an endosiphocone[20] with an apical angle of about 8°. It is badly bent at mid-length, and retains there part of the camerate portion of the conch, poorly preserved.

While endosiphocones with apical angles of 9° or 10° are most common, occasional specimens with angles distinctly lower or higher also occur.

Locality and Formation.—Middleville, New York, in the Trenton limestone.

Specimens, with one exception, all numbered 809-1. The originals of fig. 4 on plate 48 and figs. 1a, 1b, 1c, 1e on plate 49 are in the American Museum of Natural History. Fig. 1d on

[19] Pl. 21, fig. 3; pl. 23, fig. 1, of this Journal.
[20] Pl. 22, fig. 3; pl. 23, fig. 3; pl. 25, fig. 2, of this Journal.

plate 49 represents specimen 12082-1 in the State Museum of New York, at Albany.

12. CAMEROCERAS CONRAD

Genotype: **Cameroceras trentonense** Conrad. Pal. New York, vol. 1, 1847, p. 221

Cameroceras is distinguished from *Endoceras* chiefly by the character of its endocones, which in *Endoceras* are long, gradually tapering, and free from contact with the walls of the siphuncle, except at their extreme top, where, apparently, they are attached to the septal necks forming the siphuncle. The general outline of these endocones is symmetrical in every direction. In *Cameroceras* the conspicuous part of the endocones is short and rapidly tapering. Its straight part is in contact with the ventral wall of the siphuncle, while the oblique part faces toward the interior and is free from contact with the walls of the siphuncle. Immediately above this conspicuous oblique conical part, the endocone contracts more or less, sometimes only to a slight degree. It is not known definitely whether the endocone extends above this slightly contracted part for any considerable distance or not, but apparently it continues in this direction for a length of 6 or more camerae, in cylindrical form. The cylindrical part appears to be a continuation of the downward extension of one of the septal necks. It is not known whether more than one endocone may exist in the same conch. The structure of the endocone apparently is very similar to the "preseptal cone" of *Nanno* and *Suecoceras*, but the conspicuous rapidly tapering part of the endocone is beneath the camerated part of the conch in the latter genera, while it is assumed to be surrounded by the camerated part, some distance above the base of the latter, in *Cameroceras*. This location in *Cameroceras* is indicated, among other things, by the annulation of the rapidly tapering part of the endocone, especially along its free side.

Although a considerable number of endocones are at hand it still remains to determine definitely how much of the overlying cylindrical part of the siphuncular portion of the conch belongs to the endocone, how the endocone is attached to the interior of the siphuncle, and how far above the base of the conch it is attached.

13. CAMEROCERAS TRENTONENSE CONRAD

PLATE XXIV, FIGS. 1-5

Cameroceras trentonense Conrad, Jour. Acad. Nat. Sci. Philadelphia, vol. 8, 1842, p. 267, pl. 16, fig. 3; Hall, Pal. New York, vol. 1, 1847, p. 221, pl. 56, figs. 4a-c

Specimens figured by Hall.[21]—Both specimens are compressed laterally, and in each there is a tendency toward angularity on the dorsal or antisiphonal side of the conch. The dorso-ventral diameter of the shorter specimen is 24 mm., and the lateral diameter is 21 mm. Viewed from the ventral side the conch looks slightly broader than when viewed from the dorsal side. The rate of enlargement of the conch evidently was small. The dorso-ventral diameter of the longer specimen is 26 mm. and the lateral diameter is 19 mm. It is possible that this lateral compression is due to pressure during fossilization.

The number of camerae in a length equal to the dorso-ventral diameter of the conch is from three to three and a half. The sutures of the septa curve slightly downward laterally, forming shallow lateral lobes and very low dorsal and ventral saddles; this is another feature which probably is not constant in the species. The septa curve in a dorso-ventral direction with a radius of 14 mm., and laterally with a radius of 8 mm., again suggesting lateral pressure. The siphuncle is in contact with the ventral wall of the conch for a width of 3 or 4 mm., so that this side of the siphuncle does not show the annulations which cross the remainder of the siphuncle obliquely.

In the longer specimen, the conch is straight; the exposed part of the siphuncle is likewise straight; the bend at the junction of the siphuncle with a remainder of the conch evidently is due to distortion during fossilization. In the shorter specimen, the septal necks contract within the upper half of the camerae, expand within the lower half, and then contract again toward their lower margin, so as to admit of the insertion of this margin into the top of the next lower septal neck. The surface of the conch apparently is smooth.

Locality and Horizon.—Middleville, New York; in the Trenton limestone.

Specimens No. 815, American Museum of Natural History.

Multona Brook and Poland specimens.—Cross-section of conch

[21] This Journal, pl. 24, figs. 1, 2.

nearly circular, slightly depressed. In one specimen, (fig. 4), the dorso-ventral diameter equals 22 mm. and the lateral diameter 23 mm., the diameter of the siphuncle being 11 mm. The number of camerae in a length equal to the diameter of the conch is 4. The sutures of the septa are directly transverse, curving downward slightly along the median part of the ventral side and sometimes also laterally. As far as known, the septal necks extend downward the length of one camera, and invaginate into the top of the septal neck next beneath.

In the second of the specimens from Multona brook (Pl. 24, Fig. 3), the siphuncle is in contact with the ventral wall of the conch, and is flattened and not annulated along this line of contact. Around the remainder of its circumference the siphuncle is strongly annulated, in an oblique direction, the annulations forming an angle of 70° with the vertical axis of the conch. Toward the tip of the endocone the angle made by the annulations appears to become a little more acute.

The interior of the rapidly contracting part of the endocone and the adjacent part of the cylindrical siphuncle, immediately above, is lined by a calcareous deposit. In the Poland specimen (Pl. 24, Fig. 5), this calcareous deposit fills the lower part of the endocone for a distance of 7 mm. from its tip. Immediately above this level the thickness of the calcareous deposit equals 2 mm. At the upper end of the inversely conical part of the endocone, the thickness of the calcareous deposit is 1 to 1.5 mm. Four camerae farther up, within the cylindrical part of the endocone, the thickness of the calcareous deposit is reduced to half a millimeter.

Two of the specimens from Multona brook preserve casts of the interior of the endocone; one of these is figured here (Pl. 24, Fig. 3). It has proved impossible so far to determine with confidence how much of the conch is to be included in the structure here called the endocone. The conspicuous part of the endocone, which tapers rapidly downward, varies from 4 to 6 camerae in length in different specimens, but it is not known how much of the overlying cylindrical part is to be included in the endocone. In other words, it has been impossible, so far, to distinguish between the walls of the siphuncle and the walls of the endocone, or to determine at what level the top of the cylindrical portion of the endocone originates. Possibly all of the cylindrical portion

belongs to the siphuncle, and no part of this cylindrical portion to the endocone.

Locality and Horizon.—Multona brook, 2 miles northeast of Middleville, New York; specimens No. 59449, U. S. National Museum. One mile above Poland, in Herkimer county, New York; specimen 59450, U. S. National Museum. Both localities in the Trenton limestone.

14. CAMEROCERAS CALUMETTENSE SP. NOV.
PLATE XXIV FIGS. 6A-E

Specimen 65 mm. in length, consisting of part of a siphuncle traversing nine camerae in a length of 52 mm. and terminating at the base in an endocone three camerae in length. Possibly the siphuncle is one camera less and the endocone one camera more in length, since in two other specimens the endocone is four camerae in length.

In the longer specimen here figured (Pl. XXIV, Figs. 6A, B), the siphuncle narrows from a width of 12 mm. immediately above the point of departure of the endocone to 10.5 mm., 8 camerae farther up. A second specimen shows the same narrowing of the siphuncle in an upward direction.

Not only the siphuncle, but also the endocone, is flattened ventrally by contact with the ventral wall of the conch. This is indicated by 3 specimens. (Plate XXIV, Figs. 6A, C). Except along this flattened ventral part, both the siphuncle and the endocone are annulated toward the interior of the conch. The lower margin of the septal funnels, as seen on casts of the interior of the siphuncle, forms an angle of 60° to 70° with the vertical axis. Along the greater part of its length, the annulations of the siphuncle are parallel to the lines of contact with the septa, but, on approaching the upper margin of the endocone from above, the angle made by the annulations changes to 75° or 80° with the vertical, thus shortening the distances between the annulations on the dorsal side of the siphuncle.

On the ventro-lateral sides of the siphuncle, vertical sections of the septa can be traced for 6 mm. from the siphuncle. Ventrally, the siphuncle was in direct contact with the wall of the conch.

The siphuncle appears to consist of a darker exterior layer and a lighter colored interior one. The darker layer evidently is a continuation of the septum and can be traced downward the

length of one camera where its margin invaginates into the upper part of the septal neck next beneath. The lower margin of each septal neck extends about 1 mm. below the top of the underlying one. The light colored layer appears to be merely a calcareous inner lining of the darker colored one and, as far as known, also extends downward only the length of a single camera.

The interior of both the siphuncle and of the endocone (Plate XXIV, Figs. 6D, E), is lined by a calcareous deposit, which attains a thickness of about 4 mm. at the top of the endocone, diminishing to 2 mm. about 3 camerae farther up, and to about three-quarters of a millimeter 8 camerae above the top of the endocone. About half way down the length of the endocone the calcareous deposit completely fills its interior. The matrix filling the upper half of the axial part of the endocone and the overlying part of the siphuncle is obliquely annulated in a manner strictly corresponding to the annulations on the exterior of the siphuncle, but the annulations are less prominent. Passing along the axial part of the solid deposit filling the lower half of the endocone is a thin band, a millimeter or less in width, but only about one-fifth of a millimeter thick dorso-ventrally, which evidently was originally an endosiphuncle, filled in successively from above by curved transverse, thin layers whose concave sides face upward.

Locality and formation.—From the cephalopod bed at the base of the Maquoketa on Little Calumet creek, 6 miles south of Louisiana, Missouri. Collected by Ulrich and Kirk in 1911, and now in the U. S. National Museum.

15. ASCOCERAS BARRANDE

Genotype: **Ascoceras bohemicum** Barrande. Barrande, Syst. Sil. du Centre Boheme, pl. 93

The Silurian genera *Ascoceras*, *Glossoceras*, and *Aphragmites* have laterally compressed gerontic living chambers, differing in this respect from the Ordovician genus *Billingsites* in which these chambers are depressed dorso-ventrally. In the three Silurian genera the upper part of the living chamber is contracted into a tubular portion which terminates in *Ascoceras* and *Aphragmites* in a simple transverse aperture, but which in *Glossoceras* has distinct dorsal and lateral crests, with intermediate sinuses. The general transverse section of the upper tubular portion may be circular or moderately depressed dorso-ventrally. In *Ascoceras*

and *Glossoceras* the exterior of the shell is smooth. In *Aphragmites* the exterior of the living chamber is sharply annulated transversely.

In American strata the genus *Ascoceras* is represented by the species *Ascoceras indianense* Newell from the Niagaran at Delphi, Indiana, *Ascoceras southwelli* Worthen from the Niagaran at Port Byron, Illinois, and *Ascoceras townsendi* Whiteaves from the Niagaran (Guelph) at Durham, Ontario. In the last named species the gerontic group of living chambers appears to have been relatively much shorter than in typical forms of *Ascoceras*.

16. BILLINGSITES HYATT

Genotype: **Ascoceras canadense** Billings. Rep. Progress for 1853-56, 1857, Geol. Surv. Canada, p. 310; Geol. Canada, 1863, p. 318, fig. 227

Billingsites differs from typical *Ascoceras* chiefly in having the gerontic group of living chambers dorso-ventrally depressed, instead of laterally compressed as in the latter genus. The contracted part of the living chamber, above the level of the uppermost dorsal saddle, is much shorter in *Billingsites* and is more distinctly depressed dorso-ventrally. The margin of the aperture is transverse, without crests or sinuses. The genus is known so far only from the Ordovician.

The genus *Billingsites* includes *Billingsites anticostiensis* (Billings) from the Gamachian (Ellis Bay) of Gamache Bay, Anticosti; *Billingsites borealis* (Parks) from the Richmond (Shammattawa) of Shammattawa river, Manitoba; *Billingsites costulatus* (Whiteaves) from the Richmond of the Lake Winnipeg region in Canada; and *Billingsites newberryi* (Billings) from the Richmond (English Head and Vaurial) and Gamachian of English Head and other localities on Anticosti. The genotype is *Billingsites canadensis* (Billings) from the English Head and Vaurial of Anticosti.

The specimen described by Sardeson under the name *Ascoceras gibberosum*, from the Ozarkian (Oneota) of Dresbach, Minnesota, according to Dr. E. O. Ulrich belongs to a new genus of *Chiton*, related to *Priscochiton*, now under investigation.

17. BILLINGSITES (?) WILLIAMSPORTENSIS SP. NOV.

PLATE XXXV, FIGS. 2A, B, C

The specimen has the external form of the gerontic living chamber of a *Billingsites*. It is depressed dorsoventrally, and the more convex side is regarded as ventral, the less convex as

dorsal. A vertical dorsoventral section through the center of the specimen exposes two septa, of which the lower is more distinct. This septum rises from a level of 6 mm. above the base of the specimen on its ventral side to 17 mm. at a point 4.5 mm. distant from its dorsal wall. The upper septum is 4 mm. above the first on its ventral side and rises to 25 mm. above the base of the specimen at a point 1.5 mm. from its dorsal wall. The dorsal terminations of these septa are unknown; no trace of the siphuncle remains.

The lateral view reproduced as figure 2A, Plate XXXV, shows the ventral side on the left. Figure 2B on the same plate presents the ventral side, and figure 2C the dorsal.

Locality: From the Catheys formation at Williamsport, Tennessee. Specimen 48395 in the U. S. National Museum.

Remarks: This species may be a precursor of typical *Billingsites*, the rise of the septa on its dorsal side forshadowing the formation of the strongly developed dorsal saddles of that genus.

18. ORTHOCERAS BREYNIUS

The name *Orthoceras* or *Orthoceratites* was applied first by Breynius[22] to erratic specimens found in the vicinity of Danzig in Germany. From this location it may be assumed that the erratic blocks containing these specimens were either of Ordovician or Silurian origin. There is a possibility that some one visiting the original locality might be able to identify the species figured. Nothing is known as to the fate of the original specimens.

The figures published by Breynius show that the rate of enlargement of the species described by him was very small. The septa were relatively distant, about 2 camerae occurring in a length equal to the diameter of the conch. The siphuncle was small, omewhere between one-sixth and one-seventh of the diameter of the conch. Its segments were cylindrical, not enlarging within the camerae. The septa were deeply concave.

The nearest approach to *Orthoceras*, as figured by Breynius, with which the writer is familiar, is a species of *Lituites*, from Esthonia, well represented in the collection of the U. S. National Museum (Plate XXVIII, Fig. 3). In these specimens the annulations on the exterior of the shell are accompanied by very weak annulations on casts of the interior. The camerae of this

[22] Dissert. Phys. de Polythalmiis, 1732, pp. 12, 19, 31; Pl. III, Figs. 1-7.

species are relatively long, and the siphuncle is only moderately excentric.

It is evident that the type of *Orthoceras*, if this genus is to be accredited to Breynius, must be some species which could have been carried southward by glacial action to the vicinity of Danzig. If any true Orthoceroid is known which could have been the species figured by Breynius, it is desirable that attention be called to this fact.

In this connection it might be of interest to note that the genus *Lituites* was defined by Breynius in the same work in which he defined *Orthoceras*. In neither case was a binomial nomenclature used, and it is doubtful whether either genus, under these circumstances, should be ascribed to Breynius.

The species figured by Breynius is cited by Schlotheim in his description of *Orthoceras regulare*, evidently in the belief that the two were identical.

However, it is evident from his citations of figures of orthoceracones published by Bosc, Knorr, and Breynius, that he included several species under this name, and that the species figured by Breynius can not be considered the type of *regulare*.

Hyatt restricted the term *Orthoceras* to forms with smooth shell, and stated[23] that he had met but two species in North America, though doubtless others may exist. In the Zittel-Eastman Text-book of Paleontology he figured two species under *Orthoceras*, namely *intermedium* Marklin from the Silurian of Gotland, and *michelini* Barrande from the Silurian of Bohemia. Of these two species, the first differs from typical *Orthoceras* in the greater number of its camerae (about 8 in a length equal to the diameter of the conch), and in the distinct, though slight, enlargement of the siphuncle within the camerae. The second species, however, is closely similar to typical *Orthoceras* in the elongation of its camerae and in the tubular form of the segments of its siphuncle. Until the exact status of the species figured by Breynius can be determined, *Orthoceras michelini* Barrande may be accepted as the type of *Orthoceras* as restricted by Hyatt.

Typical *Orthoceras* occurs chiefly in the Silurian, but similar specimens apparently occur also in the Richmond formation, in the upper part of the Ordovician. A description of the species occurring in the Richmond at Clarksville, Ohio, follows:

[23] Hyatt, A., Genera of fossil cephalopods; Proc. Boston Soc. Nat. Hist., vol. 22, p. 275, 1883.

19. ORTHOCERAS CLARKSVILLENSE SP. NOV.

PLATE XLII

Specimen 130 mm. in length, consisting of 16 camerae, of which the uppermost is distinctly shorter, suggesting that the conch had reached full maturity. The specimen apparently enlarges from a diameter of 21 mm. at its base to 28 mm. at its top, indicating an apical angle of about 4°. Near the base of the specimen two and a half camerae occur in a length equal to the diameter of the conch. Toward the upper part, three camerae occur in a corresponding distance. The sutures are directly transverse. The septa have a concavity of 5 or 6 mm. at midlength of the specimen. The center of the siphuncle is located about one-third of the diameter of the conch from its central side. The segments of the siphuncle are cylindrical in form and their diameter is about 3 mm. along the entire length of the specimen. No part of the exterior shell remains, but the cast of the interior of the conch is smooth and it is possible that the exterior of the shell was smooth also.

Locality and Horizon.—Clarksville, Ohio; either from the Liberty or the Waynesville member of the Richmond.

Specimen No. 48255, in the U. S. National Museum.

Similar specimens have been collected by Prof. W. H. Shideler in the basal part of the Liberty at Clarksville, Ohio; and in the lower Whitewater, on Dodge creek, near Oxford, Ohio.

A similar specimen, but with somewhat more distant septae, was found in the Richmond about a mile north of the light house at the southern end of Bay de Noc peninsula, in Northern Michigan, in strata probably equivalent to the Whitewater member.[24] Additional specimens have been found in the Stonington area, farther northward on the same peninsula, by Dr. R. C. Hussey, of the University of Michigan.

Remarks.—It has not been determined to what extent the form of the segments of the siphuncle in Orthoceroids is dependent on the relative distance between the septa. In general it may be stated that in those forms in which the septa are more distant from each other the segments of the siphuncle tend to expand less within the camerae, sometimes being cylindrical, while

[24] Foerste, A., The Richmond faunas of Little Bay de Noquette in northern Michigan; Ottawa Nat., vol. 31, p. 122, pl. 5, fig. 19, 1917.

in forms in which the septa are relatively close together these segments tend to be globular or nummuloidal.

Cylindrical segments are frequent in such genera as *Dawsonoceras, Kionoceras,* and *Protokionoceras;* they occur also in some species of *Spyroceras* and *Cycloceras.* Evidently, the cylindrical form of the segments of the siphuncle is not sufficient, in itself, to determine the generic relationship of an Orthoceroid cephalopod. According to the Hyatt classification, the character of the surface ornamentation also must be taken into account.

20. GEISONOCERAS HYATT

Genotype: **Orthoceras rivale** Barrande; Syst. Sil. du Centre Boheme, pl. 209

The genus *Geisonoceras* was erected by Hyatt for the banded Orthoceroids of Barrande. A banded form differs from a transversely striated one in having the striae more distant, the upper margin of the band being abruptly defined, while the general surface of the band contracts gently and evenly in an apicad direction. Successive bands overlap each other in an oral direction. The genus probably was evolved from forms having relatively closer transverse striae. According to Hyatt, the young are either smooth or transversely striated.

Hyatt selected as the type of this genus *Orthoceras rivale* Barrande, from the Silurian of Bohemia. In this species two and a half camerae occur in a length equal to the diameter of the conch. The siphuncle is slightly excentric, and it enlarges slightly within the camerae. In the Zittel-Eastman Text-book of Paleontology he figures as *Geisonoceras* the *Orthoceras timidum* Barrande of the Silurian of Bohemia, and defines the genus without referring to its characteristic transverse banding. The genus *Geisonoceras,* however, must be regarded as founded upon *Orthoceras rivale,* the original type, and not on *Orthoceras timidum.*

In the Zittel-Eastman textbook, Hyatt defines *Orthoceras* as having a siphuncle centren or slightly dorsad of the center. The siphuncle of *Geisonoceras* is stated to be centren or slightly ventrad of the center. As applied to Orthoceroids, the terms dorsad and ventrad need some explanation. In those specimens in which the conch is distinctly though slightly curved lengthwise, the convex side usually is regarded as the ventral one. Theoretically, the ventral side should be located by the presence of an hypo-

nomic sinus. However, since Orthoceroids do not have an hyponomic sinus, this method of orienting the conch can not be used for them. When the transverse striae slope distinctly downward from one side of the conch to the other, the lower part of their course is supposed to correspond to the hyponomic sinus, at least in those forms which are not curved lengthwise. It may be acknowledged freely that in the present state of our knowledge of the Orthoceroids the terms dorsal and ventral are used loosely. In the absence of all other criteria, that side of the conch which is nearest the siphuncle is called the ventral one, at least provisionally.

Banding is by no means confined to the genus *Geisonoceras*. It occurs also in breviconic forms, as indicated by Hyatt,[25] and in some species of Actinoceroids.

21. CYCLOCERAS McCOY

The genus *Cycloceras* was defined by McCoy[26] as consisting of "those conical species marked with prominent concentric rings, and having the surface frequently sculptured with transverse scaly laminae, and often decussated; siphuncle dorsal." This description is accompanied by a small figure with vertical striae or ribs, but the figure does not resemble any species described or listed by him in the text. Among the species known at that time, it most resembles *Orthoceras rugosum* Fleming, as represented by Phillips,[27] and that species is therefore regarded here as the genotype. In this figure the annulations are tuberculated by longitudinal echinated lines, of which there are apparently about 18 on the entire circumference of the conch. The expression, "siphuncle dorsal," at present would be changed to siphuncle ventral.

None of the species described or listed by McCoy in the body of his text agrees with his description of the genus in the possession of vertical lines of any kind. The first species mentioned was originally described by Fleming[28] as *Orthocera annularis*. Fleming's illustration is reproduced herewith as figure 4, plate XXV. The surface of this species is said to be smooth, except

[25] Hyatt, A., op. cit., p. 275.
[26] Syn. Carb. Foss. Ireland, 1844, p. 6, fig. 6.
[27] Geology of Yorkshire, 1836, pl. 21, fig. 16. See also Fleming, Ann. Phil. vol. 5, 1815, p. 203, pl. XXXI, fig. 9.
[28] Ann. Phil., vol. 5, 1815, p. 203, pl. 31, fig. 8.

for the annulations. A larger form was given the same name by Phillips[29] and his illustration is here reproduced as figure 5, plate XXV. Lts surface had annular ridges and intervening waved striae. The second species described by McCoy is *Cycloceras laevigatum* McCoy, represented by him as figure 3 on his plate 1. At the time of the original description no transverse striae were known. Probably the type was a cast of the interior of the conch, on which the surface striae leave no impress. Later Foord[30] figured specimens of the same species in which transverse striae are present where the shell is preserved. His illustrations are reproduced herewith as figures 3A and 3B on plate XXVII. Possibly the surface of the shell of *Orthocera annularis* Fleming was similarly striated.

The third species described by McCoy under *Cycloceras* was the form described by Phillips[31], in the body of his text,, as *Orthoceras annulatum,* but which in his description of plates he referred to *Orthoceras annulare.* This form possesses transverse striae in addition to the annulations, but there are no vertical striae or ribs. It is the only one of the three forms listed by McCoy in which transverse striae were known to be present at the time of the description of his genus *Cycloceras.* McCoy identifies this species with *Orthoceras lineolatum* Phillips and cites the description based on the specimen represented in this Journal on pl. XXV, (fig. 5).

It appears, therefore, that McCoy included in his genus *Cycloceras* at least two distinct types of structure. In one, the annulations were tuberculated where crossed by longitudinal lines; in the other only transverse striae were present in addition to the annulations. The first type of structure is that indicated by his original description and the accompanying small figure. The second type of structure is that of the three species mentioned by McCoy in the body of his text.

Hyatt[32] in 1883 defined *Cycloceras* as including transversely striated Palaeozoic longicones, which at some stage of their growth have annular costae. Subsequently in the Zittel-Eastman Text-book of Paleontology, he re-defined the genus as including annulated orthoceracones and cyrtoceracones with discontinuous

[29] Geology of Yorkshire, 1836, pl. 21, fig. 9.
[30] Carb. Ceph. Ireland, 1897, pl. 5, fig. 1.
[31] op. cit., p. 239, pl. 21, figs. 9, 10.
[32] Hyatt, A., op. cit., p. 275.

longitudinal ridges. The first of these definitions evidently is based on the species cited in McCoy's text. The second definition is based on the original description of the genus and the small accompanying figure. Accepting the latter as the more correct interpretation of the genus, the forms possessing only transverse striae and no longitudinal markings, have no distinct generic designation, and the term *Perigrammoceras* here is proposed.

Bassler lists under *Cycloceras* a number of species having vertical striae or ribs in addition to annulations. These include *Orthoceras crocus* Billings, *O. olorus* Hall, *O. olorus baffinense* Schuchert, *O. perroti* Clarke, and *O. teretiforme* Hall. It is not known definitely whether *Orthoceras leseuri* Clarke, *O. nicolleti* Clarke, and *O. rectiannulatum* Hall belong to the same group as the preceding list, since the finer surface structure of these species is not known, only the presence of annulations being certain. It is probable that these Ordovicion forms are distinct generically from typical *Cycloceras*, as found in Carboniferous strata. Provisionally they are associated with *Spyroceras*.

Orthoceras inceptum Foerste and its variety *acceleratum* Foerste apparently belong to *Orthoceras*, as far as known.

Orthoceras (Cycloceras) novacarlislense Foerste has sharply defined transverse striae, but no annulations. Evidently it does not belong to *Cycloceras*. Its nearest relationship probably is with *Geisonoceras*.

The transverse striae of *Orthoceras amycus* Hall, are gently frilled, and the species belong to *Dawsonoceras*.

22. PERIGRAMMOCERAS GEN. NOV.

PLATE XXVII, FIGS. 3 A, B.

Genotype: **Orthoceras laevigatum**, as figured by Foord, in Carb. Ceph. Ireland, 1897, pl. 5, figs. 1d, 1e

Orthoceracones with transverse annulations and striae, but without vertical striae or ribs. Carboniferous.

It is not known definitely whether this genus is represented in earlier strata or not. In annulated forms with transverse striae occurring in the Ordovician and Silurian it usually is possible to detect also vertical striae or ribs, if the surface is sufficiently well preserved.

23. DAWSONOCERAS HYATT

Genotype: **Orthoceras annulatum** of McGill college, Montreal

Dawsonoceras is another instance of a genus erected by Hyatt chiefly with Barande species in mind, but with an American species designated as the type. In his original description he states that the genus includes forms like *Orthoceras pseudocalamiteum* Barrande, but at the close of his description he designates *Orthoceras annulatum*, from the Museum at McGill College, as the type. The latter belongs to the species characterized by transverse annulations and transverse frilled striae. Longitudinal ridges, considerably less conspicuous than the transverse annulations, may or may not be present.

In the Zittel-Eastman Text-book of Paleontology Hyatt figures under *Dawsonoceras* the *Orthoceras annulatum* of Bohemia, after Barrande, and not the specimen in the Museum of McGill College. It is evident, from the presence of frilled transverse striae, that *Orthoceras amycus* Hall belongs in the genus *Dawsonoceras*.

In *Perigrammoceras* the transverse striae are straight and not frilled.

24. SPYROCERAS HYATT

Genotype: **Orthoceras crotalum** Hall. Pal. New York, vol. 5, pt. 2, 1879, pls. 42, 82, 113

In defining this genus Hyatt apparently had in mind chiefly groups 5 and 6 of the species of *Orthoceras* described by Barrande, but, when it came to selecting the genotype, he chose *Orthoceras crotalum* Hall from the Hamilton formation of New York.

The conch of *Orthoceras crotalum* is crossed transversely by strong, sharply defined, and rather distant annulations. The vertical striae are very fine and closely crowded. A similar species, with closely crowded vertical striae, but with wider and less sharply elevated annulations, is found in the Richmond of Anticosti.

In general, however, the earlier species of *Spyroceras*, in the Ordovician, have stronger and less crowded vertical markings, often designated as ribs, or as ribs alternating with vertical striae. These may form a group distinct from the finely striated forms.

25. LOXOCERAS McCOY

PLATE XXVIII, FIGS. 2A, B

Selected genotype: **Loxoceras distans** McCoy

The genus *Loxoceras* was defined by McCoy as consisting of orthoceracones "in which the section is oval, the septa waved and placed obliquely with respect to the axis of the shell, and the siphuncle is excentric." This description is accompanied by a figure,[33] in which the sinuosity of the sutures of the septa agrees with that of *Loxoceras distans* McCoy, though the septa are drawn closer together. A study of the figures presented by McCoy in connection with his generic descriptions, in the volume cited, suggests that these figures were intended to be diagrammatic, and not accurate representations of type specimens. Moreover, he certainly never intended the first species described in the text under this generic name to be accepted as the type. Had he done so, he would not have published *Orthoceras breynii* Martin (Plate XXV, Fig. 3) first, but would have selected the one he published second, namely *Loxoceras distans* McCoy, which differs from the figure accompanying the original description of the genus chiefly in having more distant septa. The sutures of *Orthoceras breynii* present undulations, but of moderate obliquity compared with typical *Loxoceras*, and the siphuncle is located near the middle of that broad side of the conch along which the sutures curve moderately downward.

In *Loxoceras distans*, on the contrary, the sutures of the septa are strongly oblique in a sigmoid direction, and the location of the siphuncle is central. The word *Loxoceras* means oblique horn, and evidently refers to the strongly oblique sutures.

The siphuncle of *Orthoceras breynii* Martin is described by McCoy as follows:

"Siphuncle small, and a little within the margin, where it passes through the septa, but dilated between them into depressed spheroidal beads, about twice as wide as long, and touching the surface throughout the length of the shell; interior of the siphon traversed by a small continuous tube, attached to the inner walls of the dilated portion by radiating, vertical, shelly partitions (about eight in a whorl), constricted by transverse stronger partitions in the middle of each dilation (or intermediate between the septa). Surface, (of the shell) indistinct, apparently marked with fine, obtuse, transverse striae. The proportion of

[33] McCoy, Syn. Carb. Foss. Ireland, 1844, p. 6, fig. 3.

the long and short diameter of the section is as 100 to 85. A specimen five inches long is one inch three lines wide at the large end, and two lines wide at the apex, the dilated part of the siphon at the latter point equalling the whole diameter of the shell, but being only 5 lines wide at the anterior (upper) end, where two chambers occupy a space of slightly less than half an inch, while six chambers occupy the same space at the smaller end. The internal structure is that of *Actinoceras* Stokes, though it is marginal in position, and the septa are more oblique."

McCoy evidently had not a very clear idea as to the limits of his genus *Loxoceras*. This is shown by the fact that the species described third under *Loxoceras*, namely *Loxoceras incomitatum* McCoy, does not have the strongly oblique sutures. His fourth species was *Orthoceras laterale* Philips. The longitudinal view presented in Figure 3 accompanying the original description of the genus is regarded here as a diagrammatic representation of his species *Loxoceras distans*, while the small cross-section is intended to show the course of the sutures in *Orthoceras breynii*, the siphuncle of the latter being located along the middle of that broad side along the median line of which the sutures curve moderately downward.

26. SACTOCERAS HYATT

Genotype: **Orthoceras richteri** Barrande. Syst. Sil. du Centre Boheme, pls. 318, 349

Orthoceracones with relatively small siphuncles, the segments of the latter nearly spherical or slightly elongated. Septal necks short, enveloped on the interior of the siphuncle by lunate calcareous deposits, which enlarge as in other *Actinoceroids*. Sutures of the septa directly transverse. Described from the Silurian.

It is doubtful whether the Carboniferous species *Loxoceras distans* is to be regarded as congeneric with *Sactoceras*. Using the former as the type of *Loxoceras*, there appears to be use for *Sactoceras* as the designation of a distinct group, certainly present in the Silurian, and apparently beginning with forms in the Ordovician in which calcareous deposits of an Actinoceroid nature are unknown.

27. ELRODOCERAS GEN. NOV.

Genotype: **Crytoceras indianense** Miller

Conch Actinoceroid, cyrtoceraconic at the base, relatively straight at later stages of growth. Siphuncle ventrad of the center of the conch. Segments of the siphuncle presenting moderately convex vertical outlines; general form barrel-shaped, the end flat, and in contact with the intervening part of the septa. Surface of the conch transversely striated or banded as in the banded orthoceracones included by Hyatt under *Geisonoceras*. The bands curve downward along the ventral side of the conch, indicating a shallow but distinct hyponomic sinus.

Rhynchorthoceras Remele belongs to the Lituitidae, a family confined to the Ordovician.

The name *Elrodoceras* is proposed in honor of Dr. Moses N. Elrod, an indefatigable collector long living at Hartsville, Indiana.

28. ELRODOCERAS INDIANENSE (MILLER)

PLATE XXXV, FIGS. 1A, B; PLATE XXXVI, FIGS. 1A, B; PLATE XXXVII, FIGS. 2, 3; PLATE XXXVIII, FIGS. 2, 3

Crytoceras indianense Miller; 17th Ann. Rep. Dep. Geol. Nat. Res. Indiana, 1892 p. 698, pl. 18, figs. 1, 2

Rhynchorthoceras dubium Hyatt; Proc. Amer. Phil. Soc., vol. 32, 1894, p. 512

St. Paul type.—Early stages cyrtoceraconic, later stages relatively straight. The lengthwise convex curvature along the lower end of the ventral side has a radius of about 40 mm., the corresponding concave curvature of the dorsal side being much less. The specimen includes 15 camerae, in addition to which a trace of a segment of the siphuncle is seen at its base. Along the upper 9 or 10 camerae the ventral side of the conch is straight lengthwise. The sutures of the septa are directly transverse to the conch. The siphuncle is well exposed within the upper 4 camerae. Within the uppermost camera, its maximum diameter is 23 mm., narrowing to 19 mm. at the septa. The septa wedge in between the successive barrel-shaped segments, the central passage through the septa being 12 mm. in diameter. At the septa, the siphuncle is 12 mm. distant from the ventral wall of the conch, and about 23 mm. from its dorsal wall, the entire diameter being estimated at 54 mm.

The uppermost segment of the siphuncle exposes a cast of its interior; the latter is marked vertically, both above and below an irregular transverse line which crosses the cast not far above

mid-height. This transverse line indicates where the calcareous deposits enveloping the successive septal necks of the siphuncle meet, as in other Actinoceroids. At the top of the specimen, the interior of the siphuncle shows an irregular central depression, probably corresponding to the so-called endosiphuncle of Actinoceroids.

The interior of the camerae is occupied by a calcareous deposit, showing a few cystoid markings, and also a tendency toward pseudo-septa.

The exterior surface of the shell is striated transversely by narrow bands, abruptly limited along their upper margins, but more gradually sloping toward their lower margins. About 14 to 16 transverse striae occur within a length of 10 mm. On the dorsal and lateral sides of the conch these striae are directly transverse, but along the ventral side they curve gently downward.

Locality and Horizon.—St. Paul, Indiana, in the Laurel limestone (Silurian).

Specimen No. 633, in the Indiana State Museum, at Indianapolis, Indiana.

Hartsville type.—The second specimen figured by Miller, in his original description of *Cyrtoceras indianense*, consists of 11 camerae. The lengthwise convex curvature of the ventral side along the 3 lower camerae has a radius of 45 mm.; the fourth camera is distinctly less curved, and the ventral side of the upper part of the conch is straight. In a corresponding manner, the dorsal side of the specimen is concavely curved along the 3 or 4 lower camerae, and becomes straight farther up. The dorso-ventral diameter enlarges from 29 mm., at the top of the third camera from the base, to 36 mm. at the top of the seventh camera, the intervening distance being 45 mm. This suggests an apical angle of 9° along the straight part of the specimen. The specimen is curved laterally, especially along the lower part.

There are three camerae in a length equal to the dorso-ventral diameter of the conch at mid-length of the specimen. The upper four segments of the siphuncle are exposed. Their height is 11 mm. They are represented by deposits lining the interior of their walls. From these deposits it is evident that the diameter of the segments enlarges scarcely 2 mm. on passing from their contact with the septa to their greatest diameter at mid-height. Where the dorso-ventral diameter of the conch is 36 mm., the

maximum diameter of the segments of the siphuncle is 13 mm. At its passage through the center of the septum the siphuncle is constricted abruptly to a diameter of 5 or 6 mm. The outer surface of the deposit which lines the inner side of the walls of the segments of the siphuncle is corrugated vertically. A short distance above mid-height of the segments, these corrugations are interrupted by a horizontal groove. This groove marks the line at which deposits embracing successive septal necks meet.

The thickness of the shell is somewhere between one-half and three-quarters of a millimeter. Its outer surface is striated or banded transversely. Along the lateral sides of the conch these striae are directly transverse, but along its ventral side they curve downward moderately, locating the hyponomic sinus.

Locality and Horizon.—From Hartsville, Indiana, at the top of the Laurel limestone, immediately beneath the Waldron shale.

Specimen No. 6056, In the Walker Museum at Chicago University.

Rhynchorthoceras dubium.—The type of *Rhynchorthoceras dubium* is curved at its base, but straight farther up. One of the lateral sides retains the surface striae, curving downward ventrally. The opposite lateral side exposes the sutures of the septa. The conch is slightly compressed laterally, and the siphuncle is located ventrad of the center of the conch. A second specimen, not described by Hyatt, shows very well the downward curvature of the transverse striae along the ventral side of the conch. The opposite side exposes the sutures of the septa, which are directly transverse. The siphuncle is seen at the top of the specimen. (Plate XXXV, Figs. 1A, B.)

Locality and Horizon.—Hyatt referred to his type as occurring in the Niagara group of Indiana. The exact locality is unknown, but it probably came from the upper part of the Laurel limestone in the St. Paul or Hartsville area. This type is numbered 2132 in the Museum of Comparative Zoology at Harvard University. The second specimen is numbered 2133.

Joliet specimen.—One specimen includes, at its base, part of the lengthwise curved portion. The transverse striae curve distinctly downward on the ventral side of the conch. There is a tendency toward obscure transverse costae, which slope obliquely downward from the dorsal toward the ventral side of the conch at a rate much more rapid than that of the transverse striae.

One of the segments of the siphuncle, at the base of the specimen, exposes the deposit lining the interior of the siphuncle, and the abrupt constriction of the siphuncle where it passes through the septum. Specimen No. 22920, in Walker Museum at Chicago University. A fragment of a siphuncle, showing the abrupt constriction of the siphuncle, is referred to the same species. It (Plate XXXVIII, Fig. 3) is numbered 22916 in the same museum. Both are from the Niagaran.

Lemont specimen.—A specimen (Plate XXXVII, Fig. 3) exposing the structure of the interior of the conch, from the Niagaran at Lemont, Illinois, is numbered 22917 in Walker Museum.

29. TRIPTEROCERAS HYATT

Genotype: **Orthoceras hastatum** Billings. Geol. Surv. Canada, Rep. Progress for 1853-56, published in 1857, p. 333

Original Description: *Tripteroceras* has similar forms and sutures to *Eudoceras*, but the lateral saddles are acute. The venter is flattened, and broader than the dorsum, which forms the apex of the subtriangular section. The siphon is ventral and nummuloidal, and the whorl arcuate in the young, though straight in the full grown, and the aspect altogether distinct from the shells of *Eudoceras*. The young are similar to the adults of *Eudoceras*.[34]

The genotype is *Orthoceras hastatum* Billings. An examination of the types in the Victoria Memorial Museum at Ottawa, Canada, shows that these types include two species, one of which is described here as *Tripteroceras pauquettense*.

The siphuncle of *Orthoceras hastatum* was described by Billings as small, close to the centre of the ventral margin. The absence of any further description of the siphuncle suggests that, at the time the original description of this species was being prepared, the specimen here called *Tripteroceras pauquettense* did not form part of the type series of *Orthoceras hastatum*, but was added subsequently. The siphuncle of typical *Orthoceras hastatum* appears to be narrow, and not nummuloidal. Omitting this one word, nummuloidal, the remainder of Hyatt's description of the genus *Tripteroceras* will stand, with typical *Orthoceras hastatum* as the genotype.

The conch is strongly depressed dorso-ventrally. The cross-section is depressed subtriangular, with the ventral side distinctly

[34] Hyatt, A., op. cit., p. 287.

flatter than the dorsal. The lateral sides are rapidly rounded. The sutures form broad dorsal and ventral lobes. The lateral saddles are relatively high. Usually the conch is straight, though several specimens of *Orthoceras hastatum* are curved slightly lengthwise. In Hyatt's generic description the conch is described as having the whorl arcuate in the young.

30. TRIPTEROCERAS HASTATUM (BILLINGS)

PLATE XXXI, FIGS. 3A, B, C, D

Orthoceras hastatum Billings, Geol. Surv. Canada, Rep. Progr. for 1853-56, published in 1857, p. 333

Original Description: Shaped like a *Theca,* two-edged; ventral side broad and almost flat, slightly convex; dorsal aspect most convex along the center, thence sloping to the sides, which are perpendicular to the ventral aspect, and nearly flat in the larger portion of the shell. The section is thus a low, broad-based triangle, with the angle at each end truncated, and with the apical angle rounded. At a lateral diameter of eleven lines the height or dorso-ventral diameter is six lines; the rate of tapering is about 4 lines to the inch, measuring the inclination of the sides; the ventral and dorsal aspect approach each other at the rate of two lines and a-third to the inch; siphuncle small, close to the centre of the ventral margin; the septa are curved in a circle of which the radius is about half-an-inch, their distance from each other has not been satisfactorily ascertained; near the apex the sides consist of two rounded edges, but in the direction of the aperture these become more and more broadly truncated, until at a diameter of eleven lines they have a perpendicular width of about two lines. The surface is coarsely striated transversely, and, at the dorsal ridge, the striae appear to make a bend toward the aperture.

Locality and Formation.—Black River and Trenton limestone, Pauquette's Rapids, Ottawa City.

Five specimens, numbered 1281, and lettered *a, b, c, d,* and *e* respectively, are in the Victoria Memorial Museum. Of these, specimen 1281a is regarded here as the type, since it is 11 lines wide; a septum truncates its upper end. Specimen 1281c, with a septum at its lower end, comes next in size. Specimen 1281d, here figured, shows the lengthwise curvature at its apical end, with the concave curvature on its dorsal side; it is ter-

minated both at top and bottom by a septum. Specimen 1281b is smaller, but shows a similar lengthwise curvature. Specimen 1281e shows the apical end. (Specimen 1281 is described here as *Tripteroceras pauquettense*, and does not properly belong to the type series of *Orthoceras hastatum*.)

The conch of specimen 1281d, here figured, enlarges with a lateral apical angle of 20°. The ventral side is strongly flattened. The dorsal side shows a slight tendency toward angularity along its median line. From this median line toward the lateral angles, the dorso-lateral sides are slightly flattened. The lateral angles are abruptly rounded. Toward the apical end, the specimen is gently curved lengthwise. The sutures of the septa curve evenly downward on both the dorsal and the ventral sides. The siphuncle is close to the ventral side, but its structure is unknown. The lines of growth are almost directly transverse around the entire specimen, but on the ventral side their direction is very slightly concave upward, and on the dorsal side there is a corresponding but almost imperceptible concave curvature which is interrupted medially by an almost imperceptible convex curvature.

31. TRIPTEROCERAS PAUQUETTENSE SP. NOV.
PLATE XXXI, FIGS. 2A, B, C, D

Orthoceracone strongly compressed; at its upper end the lateral diameter is 24 mm. and the dorso-lateral one is 15 mm. The cross-section is slightly subtriangular, owing to the smaller convexity of the ventral side. The dorsal side is quite regularly rounded and forms about two-fifths of a circle having a radius of 13 mm., while the ventral side forms about one-fifth of a circle having a radius of 20 mm. The lateral margins are rapidly rounded. The center of the siphuncle is 4 mm. from the ventral wall. It enlarges from a diameter of 4 mm. at the septa to 5 mm. at mid-height within the camerae. Its passage through the septum is 1.5 mm. in diameter.

The specimen is 25 mm. in length. Six camerae occur in a length of 24 mm. On the ventral side of the conch, the sutures of the septa curve strongly downward toward the median line, but, on approaching the lateral outline of the conch, this curvature of the sutures becomes slightly convex. Along the median line of the ventral side the downward curvature of the sutures

is slightly angular. On the dorsal side of the conch, the downward curvature of the sutures is more moderately and more evenly concave. The lateral outlines of the conch diverge at an angle of 11°. No growth lines are preserved on the exterior of the shell.

Locality and Horizon.—Pauquette Rapids, in the Ottawa River, Canada; in the Leray member of the Black River.

Remarks.—The specimen here described is numbered 1281 in Victoria Memorial Museum, at Ottawa, Canada, and is there found among the types of *Orthoceras hastatum* Billings, from which it is here separated as a distinct species.

The specimen here described as *Tripteroceras pauquettense* probably is distinct generically from typical *Tripteroceras*. The latter probably contains only species with moderately expanded siphuncular segments, species with nummuloidal segments probably being referable to a distinct genus.

32. CHARACTOCERAS GEN. NOV.

Genotype: Trochoceras (?) baeri Meek and Worthen. Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 263; Meek, Geol. Surv. Ohio, Pal., 1, 1873, p. 157, pl. 13, fig. 9.

Conch nautiloid, depressed dorso-ventrally, the dorsal side being impressed at contact with the ventral side of the preceding volution. The transverse striae indicate that the margin of the aperture curved increasingly downward from the dorsal side of the conch toward its ventral side, the hyponomic sinus being broad and relatively deep, but not abrupt. The sutures of the septa curve moderately downward laterally, rising farther on the ventral than on the dorsal side. The siphuncle is located near the ventral side, but not in contact with the latter. The segments of the siphuncle are somewhat between subfusiform and elongate elliptical in outline.

The conch of *Uranoceras* Hyatt is compressed laterally, and there is no dorsal furrow, although adjacent volutions often are so close as to touch each other. The sutures of the septa are more sinuous laterally, at later stages of growth. The siphuncle is only slightly ventrad of the center of the conch, and the downward curvature of the septal necks is distinct. The form of the segments is elongate cylindrico-elliptical. The genotype is *Uranoceras uranum* Barrande, from the Silurian of Bohemia.

In *Litoceras* Hyatt, the cross-section of the conch is broadly kidney-shaped; the ventral side presents a semicircular outline, which rounds rapidly into the broadly impressed dorsal side of the conch. The siphuncle is located distinctly dorsad of the center, except in younger stages of growth. Since the genotype, *Litoceras whiteavesi* Hyatt, is from the Canadian of Newfoundland, it may be assumed that the segments of this siphuncle were curved cylindrical, and not elongate elliptical or subfusiform in outline. *Litoceras* does not occur in the Richmond formation.

Charactoceras includes also *Nautilus hercules* Billings, from the Charleston formation (Richmond) of Anticosti. *Eurystomites plicatus* Whiteaves, from the Lake Winnipeg area, apparently is congeneric.

33. CHARACTOCERAS BAERI (MEEK AND WORTHEN)

PLATE XXXI, FIG. 1; PLATE XXXII, FIGS. 1A, B; PLATE XXXIII, FIGS. 1A, B; PLATE XXXIV, FIGS. 1A, B, 2

Trochoceras (?) Baeri Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 263. Meek, Geol. Surv. Ohio, 1, 1873, p. 157, pl. 13, fig. 9.

Type specimen.—The type was collected at Richmond, Indiana. It consisted of a phragmacone, defective on one side, showing neither surface structure, nor the siphuncle. The dorsal side of each volution is impressed distinctly by the ventral side of the preceding volution. The type is illustrated in volume 1 of the Paleontology of Ohio, and in this volume it is stated that fragments from the same locality and position as the type have the siphuncle located rather more than its own breadth outside of the center. Better specimens, collected by Prof. W. H. Shideler from the Richmond at Oxford and vicinity are described in the following lines.

Oxford specimens.—Maximum diameter of the largest well preserved specimen found, (Plate XXXI, Fig. 1; Plate XXXII, Figs. 1 A, B; see also Plate XXXIII, Figs. 1 A, B), from the ventral margin of the aperture to the opposite side of the last volution, 150 mm.; diameter at right angles to the latter, also across the umbilicus, 113 mm. Lateral diameter of the living chamber at the base of the hyponomic sinus, 93 mm.; dorsoventral diameter at the same point, 66 mm. Length of living chamber from suture at base to lower part of hyponomic sinus, measured along the ventral side, about 100 mm.; length to highest

part of the lateral margins of the aperture, measured along the median part of the lateral sides, about 108 mm. Depth of hyponomic sinus below level of highest part of lateral margins of aperture, 36 mm.

At the base of the hyponomic sinus the lateral diameter of the living chamber is 93 mm.; 100 mm. farther down, measured along the ventral side of the conch, this diameter is 83 mm.; 100 mm. still farther down it is 67 mm.; indicating a rate of diminution of 10 and 16 mm. respectively in the distances mentioned. Estimating the remainder of the length of the last volution, in an apicad direction, as 120 mm., the lateral diameter of the conch at the beginning of its last volution, was at least as small as 47 mm., but probably was smaller, since the rate of diminution of the lateral diameter of the conch appears to have been greater in an apicad direction. In fact, in some specimens, which show parts farther apicad, the rate of diminution of parts narrower than 47 mm. equals 25, and occasionally even 28 mm. in a length of 100 mm. The apical end of the conch has not been discovered, but it is estimated that the large conch here described included at least 2 complete volutions and possibly more or less of a third volution. The umbilicus may have been penetrated by a perforation about 10 mm. in diameter, but this part is not well preserved in any specimen.

The conch is depressed dorso-ventrally, the general outline of a cross-section of the larger volution being transversely elliptical, with the dorsal side distinctly and broadly impressed. The ratio of the dorso-ventral to the lateral diameter varies from 67% to 70% in different specimens. The ventral side is less strongly curved than the dorsal, the maximum curvature of the lateral sides being slightly nearer the ventral side of the whorl. In general, the lateral sides of the whorl converge toward the dorsal side. In one specimen, with a width of 66 mm. at the base of the living chamber, the width of the impressed zone at this point was 25 mm., its depth being 4 mm. In its original condition the conch was symmetrical, but, in the fossil state, one of the lateral sides often is flattened slightly or more distinctly; usually on that side of the specimen which, in the original position of the fossil in the rock, faced downward. In those specimens in which one of the lateral sides is flattened, the opposite side usually shows the normal transverse convexity.

The number of camerae in a length equal to the lateral diameter of the conch, varies in different specimens. In the large specimen described above, 7 camerae occur in this length, if measured along the ventral side of the conch. Specimens with 6 camerae in this length are more common, and a few specimens with 5 camerae in this distance occur. Close study fails to show any specific differences accompanying this variation in the relative number of camerae.

The sutures of the septa rise moderately from the dorsal toward the ventral side of the conch, the amount of this rise varying from slightly more than the height of one camera, along the ventral side, to about one and a half camerae. Along the lateral sides these sutures curve slightly downward, forming very shallow lobes, readily detected only toward the upper part of the phragmacone. Along the ventral side the sutures arch moderately upward, producing low, broad saddles. The middle part of these saddles tends to be less curved than the lateral parts, and in some specimens there is a faint downward curve of the sutures along the median line of the ventral side, but this is by no means a constant feature.

The septa are moderately concave, their curvature being greater dorso-ventrally than laterally. The siphuncle is located on the ventral side. Its distance from this side varies from one-fifth to two-sevenths of the dorso-ventral diameter.

In the specimen from Flat Fork, (Plate XXXIV, Fig. 2), three and a half miles northeast of Oregonia, Ohio, the center of the siphuncle is 5.5 mm. distant, where the dorso-ventral diameter is 36 mm. The segments of the siphuncle vary from 5.5 to 6 mm. in diameter dorso-ventrally, at mid-height of the camerae, diminishing to 4, or even 3 mm. where in contact with the septa, the passage through the septa being still narrower. Along the dorsal side of the siphuncle, the vertical outline of the segments is more evenly convex; but along the ventral side the vertical outline is distinctly convex above and concave below, the concave part being adnate to the septa beneath for a length of 3 to 5 mm. The upper part of the dorsal outline of some of the segments is adnate for a length of 1 to 3 mm. to the overlying septa, while in other segments no adnation is noted. The septal neck of this specimen appears to be very peculiar in construction. On the dorsal side of the siphuncle the septum maintains an even

rate of curvature as far as the most constricted part of the exterior wall of the siphuncle, and then appears to continue into the interior of the siphuncle for a distance of 1 mm., bending downward at an angle of 25° with a direct continuation of its course. On the ventral side of the siphuncle the septum curves gradually downward where in contact with the lower half or third of the overlying segment of the siphuncle, until reaching the most constricted part of the exterior wall of the siphuncle, beyond which it appears to extend into the interior of the siphuncle about half a millimeter in a direction toward the similar extension of the dorsal part of the septum. As a result the open passage through the center of the siphuncle appears to be constricted here to a narrow opening varying from 2 to 3 mm. in diameter. This constriction of the interior of the siphuncle, beyond the amount of constriction indicated by the exterior wall of this siphuncle, is not noted in all specimens, though traces of such constriction occur also in several of the segments in specimens obtained at Four Mile creek, near Oxford, Ohio. It is not regarded as a constant feature. Apparently it is not strictly a part of the septa, but was formed subsequent to the latter.

In some specimens from 8 to 10 of the upper camerae are considerably shorter in length than the camerae beneath, indicating a rather long period of gerontic growth.

The surface of the shell is transversely striated by lines which tend to occur at regular intervals, about 16 in a length of 20 mm. where the lateral diameter is 85 mm. Since similar distances obtain also toward the apical end, where the diameter is much less, the striae here appear relatively more distant. In some specimens the striae are more numerous, equalling 20 and even 24 in a length of 20 mm. In general, these striae are of the "banded" form, or they may be very narrow and sharply defined, and separated by much broader flat areas. These transverse striae follow the same course as the former limits of the aperture. Along the median part of the dorsal side they are nearly directly transverse, but dorso-laterally they curve increasingly downward, their ventral course being broadly concave, forming broad and deep lobes here, whose bases lie about 5.5 camerae below the level of these striae on the dorsal side of the conch. These lobes mark former positions of the hyponomic sinus.

Locality and Horizon.—This species was described from Rich-

mond, Indiana. The large specimen forming the basis of most of the description here presented was obtained on Dodge's Fork, near Oxford, Ohio, at the base of the Whitewater member of the Richmond formation. Numerous specimens from the same horizon, on Little Four Mile creek, also near Oxford, furnished additional material, including sections of the siphuncle. However, most of the details of the structure of the siphuncle here presented were obtained from a specimen collected by Prof. J. E. Carman on Flat Fork, three and a half miles northeast of Oregonia, Ohio, at the base of the Whitewater. The specimens from the vicinity of Oxford belong to Miami University and were collected by Professors W. H. Shideler and S. R. Williams.

A closely similar, if not identical, species occurs at the base of the *Rhynchotrema dentata* bed in the Upper Whitewater, on Beasley Run, north of Camden, Ohio.

Specimens resembling *Charactoceras baeri* occur in the Fernvale member of the Richmond at Wilmington, Illinois, and Cape Girardeau, Missouri.

34. ONCOCERAS HALL

Genotype: **Oncoceras constrictum** Hall. Pal. New York, vol. 1, 1847, p. 197, pl. 41, figs. 6 a-f, 7 a-d

Conch curved lengthwise; the lengthwise curvature of the ventral side is convex, and the general curvature of the dorsal side is concave, but along the upper part of the phragmacone and the lower part of the living chamber the vertical outline of the dorsal side changes to distinctly, though moderately, convex. The gibbosity of the dorsal side of the conch usually extends also laterally sufficiently to be noticeable when the conch is examined from the ventral side. The conch is slightly compressed laterally. The living chamber narrows toward the aperture, which is broadly oval in outline, the angularity being on the ventral side. The hyponomic sinus is shallow. The siphuncle is close to the ventral wall of the conch, and its segments are narrowly fusiform.

Oncoceras abruptum Hall, *Gomphoceras cincinnatiense* Miller, *Oncoceras douglassi* Clarke, *Oncoceras pristinum* Ruedemann, and *Orthoceratites trentonense* Emmons are congeneric. The last named species from the Trenton of New York apparently is identical with *Oncoceras constrictum*. *Gomphoceras faberi*

Miller may belong here, though its dorsal outline is only faintly convex.

35. ONCOCERAS CONSTRICTUM HALL

PLATE XXXIX, FIGS. 2A, B, 3, 4

Oncoceras constrictum Hall, Pal. New York, vol. 1, 1847, p. 197, pl. 41, figs. 6 a-f, 7 a-d

Type.—Among the specimens figured by Hall that represented by figures 6 a, b, c may be selected as the type, not only because it is the first in the series of illustrations, but also because it is the largest, and evidently is a fairly typical example of the species as now known.

Conch curved lengthwise, slightly compressed laterally, and distinctly gibbous at the base of the living chamber and the top of the phragmacone, the gibbosity being conspicuous dorsally as well as laterally and ventrally. The radius of convex curvature of the vertical ventral outline is 30 mm. for the greater part of the length of the specimen, but at its apical end the rate of curvature is slightly greater. The dorsal side has a general concave curvature with a radius of 45 mm., but for a distance of 8 or 9 mm. both above and below the base of the living chamber the dorsal outline changes to slightly convex, producing a conspicuous gibbosity here. Toward the apical end of the specimen the rate of concave curvature increases to a radius of less than 20 mm.

The conch is compressed laterally. At the base of the living chamber, where the dorso-ventral diameter is 24 mm., the lateral diameter is 20 mm. Toward the aperture the conch contracts not only dorso-ventrally but also laterally. At the aperture the dorso-ventral diameter is 18 mm. Since the living chamber of the specimen here described is crushed laterally, it is not suitable for showing the rate of lateral contraction toward the aperture, but in better preserved specimens the rate of contraction laterally is greater than that dorso-ventrally, resulting in a slightly oval outline of the aperture. The curvature of the conch in a transverse direction is even on the dorsal side of the conch, but tends to be faintly angular on the median part of the ventral side.

The base of the living chamber is exposed by a fracture. The height of the living chamber is about 20 mm. That part of the phragmacone which remains attached to the living chamber is

24 mm. long. At the broken base the dorso-ventral diameter is 12 mm.

The septum at the base of the specimen curves gently dorso-ventrally, and curves even less laterally. The result is that the sutures of the septa form comparatively shallow lateral lobes. Along the dorsal side of the conch the sutures are almost directly transverse, but along the ventral side they rise into more or less distinctly angular saddles. The siphuncle is small, and is located less than 1 mm. from the ventral wall even along the upper part of the phragmacone. The number of camerae in a length equal to the dorso-ventral diameter in another specimen is about 8, and in still another specimen the segments of the siphuncle are seen to be narrowly fusiform.

Figured specimens.—The original[35] of figures 3 a, b, on plate 3 of the Third Report of the New York State Museum, published in 1850, shows the surface striae very well. These striae are directly transverse along the dorsal and lateral sides of the conch as far as the middle of the lateral sides. Ventrad of these middle points the transverse lines curve gradually downward until they meet along the median part of the ventral side at an angle of about 130° in the vicinity of the aperture. The hyponomic sinus is broadly V-shaped, and its depth equals 2 or 3 mm. Judging from these transverse striae, the aperture was about 15.5 mm. long, dorso-ventrally, 12.5 mm. wide, and had a distinctly angular outline at the hyponomic sinus.

The strongly concave lengthwise curvature of the upper part of the dorsal outline of the living chamber in the specimens represented by figures 6d and 6e, on the plate accompanying the original description, probably is due in large part to pressure, both specimens being preserved in a rather soft argillaceous limestone.

In some specimens the cast of the interior of the phragmacone and of the lower half of the living chamber is marked by about 35 faint vertical ribs, none of which correspond to any structure on the exterior of the shell.

Locality and Horizon.—All of the specimens described here are from Middleville, New York, in the Trenton limestone. Numbered 824 in the American Museum of Natural History.

[35] This Journal, Pl. XXXIX, figs. 2A, B.

Miller may belong here, though its dorsal outline is only faintly convex.

35. ONCOCERAS CONSTRICTUM HALL

PLATE XXXIX, FIGS. 2A, B, 3, 4

Oncoceras constrictum Hall, Pal. New York, vol. 1, 1847, p. 197, pl. 41, figs. 6 a-f, 7 a-d

Type.—Among the specimens figured by Hall that represented by figures 6 a, b, c may be selected as the type, not only because it is the first in the series of illustrations, but also because it is the largest, and evidently is a fairly typical example of the species as now known.

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The conch is compressed laterally. At the base of the living chamber, where the dorso-ventral diameter is 24 mm., the lateral diameter is 20 mm. Toward the aperture the conch contracts not only dorso-ventrally but also laterally. At the aperture the dorso-ventral diameter is 18 mm. Since the living chamber of the specimen here described is crushed laterally, it is not suitable for showing the rate of lateral contraction toward the aperture, but in better preserved specimens the rate of contraction laterally is greater than that dorso-ventrally, resulting in a slightly oval outline of the aperture. The curvature of the conch in a transverse direction is even on the dorsal side of the conch, but tends to be faintly angular on the median part of the ventral side.

The base of the living chamber is exposed by a fracture. The height of the living chamber is about 20 mm. That part of the phragmacone which remains attached to the living chamber is

24 mm. long. At the broken base the dorso-ventral diameter is 12 mm.

The septum at the base of the specimen curves gently dorso-ventrally, and curves even less laterally. The result is that the sutures of the septa form comparatively shallow lateral lobes. Along the dorsal side of the conch the sutures are almost directly transverse, but along the ventral side they rise into more or less distinctly angular saddles. The siphuncle is small, and is located less than 1 mm. from the ventral wall even along the upper part of the phragmacone. The number of camerae in a length equal to the dorso-ventral diameter in another specimen is about 8, and in still another specimen the segments of the siphuncle are seen to be narrowly fusiform.

Figured specimens.—The original[35] of figures 3 a, b, on plate 3 of the Third Report of the New York State Museum, published in 1850, shows the surface striae very well. These striae are directly transverse along the dorsal and lateral sides of the conch as far as the middle of the lateral sides. Ventrad of these middle points the transverse lines curve gradually downward until they meet along the median part of the ventral side at an angle of about 130° in the vicinity of the aperture. The hyponomic sinus is broadly V-shaped, and its depth equals 2 or 3 mm. Judging from these transverse striae, the aperture was about 15.5 mm. long, dorso-ventrally, 12.5 mm. wide, and had a distinctly angular outline at the hyponomic sinus.

The strongly concave lengthwise curvature of the upper part of the dorsal outline of the living chamber in the specimens represented by figures 6d and 6e, on the plate accompanying the original description, probably is due in large part to pressure, both specimens being preserved in a rather soft argillaceous limestone.

In some specimens the cast of the interior of the phragmacone and of the lower half of the living chamber is marked by about 35 faint vertical ribs, none of which correspond to any structure on the exterior of the shell.

Locality and Horizon.—All of the specimens described here are from Middleville, New York, in the Trenton limestone. Numbered 824 in the American Museum of Natural History.

[35] This Journal, Pl. XXXIX, figs. 2A, B.

36. MAELONOCERAS HYATT

Genotype: **Phragmoceras praematurum** Billings

Laterally compressed cyrtoceracones, with the ventral side more narrowly rounded than the dorsal. The living chambers are short, and their apertures, in the typical specimens, are contracted and pear-shaped. The sutures of the septa curve slightly downward laterally. The siphuncle is near the ventral side, and its segments are narrowly fusiform.

Cyrtoceras metellus Billings from the Canadian of Point Levis, in the province of Quebec, *Cyrtoceras falx* Billings from the Black River of Pauquette Rapids, in Ontario, and *Cyrtoceras arcticameratum* Hall from the Guelph of Ontaria are not congeneric with *Maelonoceras praematurum*. Possibly the form figured by Whitfield under *Cyrtoceras camurum* (Geol. Wisconsin, 4, 1882, p. 231, pl. 7, figs. 7-9) is a true *Maelonoceras*.

37. MAELONOCERAS PRAEMATURUM (BILLINGS)

PLATE XXXIX, FIGS. 6A, B, C; PLATE XLI, FIG. 7

Phragmoceras praematurum Billings; Canadian Naturalist, vol. 5, 1860, p. 163, figs. 20

Maelonoceras praematurum Hyatt; Proc. Boston Soc. Nat. Hist., vol. 22, 1884, p. 280

Two specimens belong to the set described by Billings under the name *Phragmoceras praematurum*, and both were figured. The specimen represented by figure 20, accompanying the original description, shows most of the details included in this description, and hence is here regarded as the type.

Type.—Conch strongly compressed laterally, and strongly curved length-wise, the siphuncle being close to the ventral side. The conch attains its greatest dimensions 5 mm. above the base of the living chamber. Here its lateral diameter is 16 mm. and its dorso-ventral one is 18.5 mm. The conch is more narrowly rounded on its ventral side, the radius of transverse curvature here being 5 or 6 mm., while that of the dorsal side is 8 mm. The convex lengthwise curvature of the ventral side has a radius of 25 mm., and that of the concave curvature of the dorsal side is about the same, at least within the limits of the type specimen.

The latter consists of the living chamber with 5 complete camerae attached. In addition, parts of 2 camerae prolong the dorsal outline of the specimen. The upper half of the living chamber narrows toward the aperture, where the lateral diameter is

12 mm., and the dorso-ventral one is 14 mm. In addition, the aperture is narrowed by two low but distinct ventro-lateral saddles, which rise above the level of the dorsal outline of the aperture and converge more or less toward each other. In the vicinity of these saddles the dorso-ventral parts of the living chamber are more or less flattened. The general outline of the aperture is pear-shaped, with the narrow part on the ventral side.

The upper part of the interior of the living chamber is distinctly constricted by a thickening of the shell. Along the dorsal and lateral sides of the aperture this thickening begins 3 mm. beneath the margin; along the ventral side it begins about 1 mm. beneath the aperture.

Along the ventral side, 5 camerae occupy a total length of 13 mm. The sutures of the septa rise slightly from the dorsal toward the ventral side of the conch. The sutures are nearly straight, their downward curvature along the lateral sides of the phragmacone being very faint. The general concavity of the septa is slight, equalling scarcely 1 mm. The siphuncle is about one-third of a millimeter from the ventral wall. Its lateral diameter, where passing through the septa, is 0.7 mm., widening to about 0.9 mm. within the camerae, the general form of its segments being only slightly fusiform.

The shell is relatively thick, equalling nearly 1 mm. along the dorsal and dorso-lateral parts of the upper half of the living chamber, and nowhere thinning to less than half a millimeter.

The transverse striae are merely lines of growth. Along the lower half of the living chamber these lines are almost directly transverse along the dorsal half of the circumference of the chamber; but on the ventral side they curve distinctly downward as far as the median part of this side. However, toward the upper part of the living chamber, the transverse striae rise more and more strongly from the dorsal toward the ventro-lateral parts of the conch, outlining successive stages in the development of the ventro-lateral saddles, which gradually increase in prominence until they attain an elevation of 2.5 to 3 mm. above the general level attained by the aperture along its dorsal side. From the crest of these saddles the lateral margins of the hyponomic sinus slope diagonally downward as far as its ventral end which descends 1 mm. or more beneath the general level attained by the dorsal side of the aperture. The general form of

the aperture is pear-shaped, with the narrow end on the ventral side. There is a tendency toward parallelism between the lateral walls of the hyponomic sinus, somewhat as in *Gomphoceras*.

Locality and horizon.—Black River limestone on LaCloche Island, in northern Lake Huron. Specimen No. 1294 in the Victoria Memorial Museum, at Ottawa, Canada.

38. MAELONOCERAS BILLINGSI SP. NOV.

PLATE XXXIX, FIGS. 5 A, B, C

Phragmoceras praematurum Billings, Canadian Naturalist, vol. 5, 1860, p. 163, fig. 19 only

The second specimen figured by Billings under the name *Phragmoceras praematurum* differs from the one here described as the type in having a shorter and straighter living chamber. It is assumed that the conch was much less curved lengthwise. Moreover, the dorsal half of the aperture is more nearly circular and the lateral walls of the hyponomic sinus are more nearly parallel.

Locality and horizon.—Lacloche Island, in the northern part of Lake Huron, in the Black River formation. Specimen No. 1294a, in the Victoria Memorial Museum, at Ottawa, Canada.

39. BELOITOCERAS GEN. NOV.

Type: **Oncoceras pandion** Hall

The group of conchs typified by *Oncoceras pandion* differs from typical *Oncoceras* in lacking a distinct gibbosity along the upper part of the phragmacone and the lower part of the living chamber. If any gibbosity along the dorsal side is present, the maximum development of this gibbosity is distinctly above the level of the base of the living chamber. Moreover, compared with typical *Oncoceras*, the conch is distinctly more flattened laterally.

The relationship of the group typified by *Oncoceras pandion* is with *Maelonoceras* rather than with *Oncoceras*. Like the latter, it is more strongly flattened laterally, and the interior of the living chamber is thickened below the margin of the aperture by an inner band which leaves a conspicuous contraction along casts of the interior of the conch. The aperture has an outline corresponding to that possessed by *Maelonoceras* during its earlier stages of growth, before the ventro-lateral saddles begin

to develop. In other words, *Beloitoceras* may be regarded as the stock from which *Maelonoceras* developed.

Cyrtoceras carrollense Worthen, *Oncoceras carvieri* Clarke, *Cyrtoceras fragile* Billings, *C. houghtoni* Clarke, *C. huronense* Billings, *C. isodorus* Billings, *C. norwoodi* Clarke, and *C. scofieldi* Clarke are congeneric; probably also an equal number of other described species of which the living chamber is not well known.

Cyrtoceras dunleithense Miller and Gurley, and *C. cordatum* Parks are characterized by the ridge-like protrusion of the siphonated side of the conch, and for these the generic term *Dunleithoceras* is proposed.

40. BELOITOCERAS PANDION HALL

PLATE XXXVI, FIGS. 5 A, B; PLATE XLI, FIGS. 4 A, B, C

Oncoceras pandion Hall; Rep. Sup. Geol. Surv. Wisconsin, 1861, p. 45, ibid, 1862, p. 41, fig. 3

Oncoceras pandion Whitfield; Mem. Amer. Mus. Nat. Hist., vol. 1, pt. 2, 1895, p. 69, pl. 9, figs. 21, 22

Type.—Conch strongly curved lengthwise, especially along its ventral side, where the radius of convex curvature is only 30 mm. Along the dorsal side the radius of concave curvature is 40 mm. The specimen enlarges from a dorso-ventral diameter of 19 mm. at its base to 25 mm. at the base of the living chamber. It diminishes to 22.5 mm. along a line drawn from 10 mm. above the base of the dorsal side of the living chamber to 14 mm. above the base of this chamber on the ventral side. Then this diameter diminishes rather abruptly, to 21 mm. within a distance of 3 mm., and to 20 mm. within an additional distance of 4 mm., above which the margin of the aperture is assumed to be. The corresponding lateral diameters are 16 mm. at the base of the specimen, 23 mm. at the base of the living chamber, 20 mm. where the abrupt contraction of the upper part of the living chamber begins, 16.5 mm. at a point 3 mm. farther up, and slightly less at the aperture. The sudden constriction of the cast of the interior of the living chamber near the aperture indicates the presence of a corresponding thickening of the interior of the wall of this chamber just beneath the aperture.

There is no trace of a gibbosity along the dorsal outline of the conch at the base of the living chamber, though the amount of concave curvature here is distinctly less. The cross-section of the conch tends to be slightly more narrowly convex on the ven-

tral than on the dorsal side, especially toward the living chamber, and most of all at its aperture, where the difference is strongly marked, resulting in the oval outline of the aperture. Faint, low, broad vertical ribs mark the cast of the interior of the conch; these number about 5 in a width of 11 mm., near the top of the phragmacone.

The number of camerae in a length equal to the dorso-ventral diameter, at the top of the series of camerae counted, is 7, when counted along the ventral side of the conch. The sutures of the septa are only slightly concave, most of the curvature being ventrad of the center of the conch. At the base of the specimen the upward curvature of the sutures is chiefly ventrad of the ventro-lateral sides. Toward the top of the phragmacone the upward curvature of the sutures begins progressively nearer the middle of the lateral sides, and the amount of the upward curvature on this ventrad side also becomes greater, the ventral saddles becoming successively higher. The siphuncle is almost in contact with the ventral wall of the conch. Its maximum width at the bottom of the specimen, within the camerae, is 3 mm., diminishing to about 1 mm. where it passes through the septa.

Locality and horizon.—Beloit, Wisconsin; in the buff part of the Black River dolomite.

Specimen No. 998, in the American Museum of Natural History.

Mineral Point specimen.—In addition to the type of *Oncoceras pandion,* Whitfield figured also a similar specimen (his figure 20) from a very fine-grained grayish rock at Mineral Point, Wisconsin. Lithologically this rock resembles that enclosing the type of *Cyrtoceras neleum,* from Platteville, Wisconsin. The Mineral Point specimen is more compressed laterally, the dorso-ventral and lateral diameters at the base of the living chamber being 26.5 and 21.5 mm. respectively. Apparently the conch is less strongly curved lengthwise, and the sutures of the septa curved less strongly upward on the ventral side. The uppermost camera is distinctly shorter than those beneath, the specimen being mature. The ventral side of the conch is more narrowly convex in cross-section than the dorsal side, especially toward the living chamber, and most of all near the aperture.

Janesville specimen.—In the specimens from Janesville, Wis-

consin, figured by Clarke,[36] the lengthwise curvature of the ventral side of the conch is similar, but the concave curvature of the dorsal side is greater, especially along the lower part of the living chamber; the conch is more compressed laterally, and the sutures do not rise as strongly on the ventral side of the phragmacone.

Oncoceras carvieri Clarke[37] appears to be closely related to the Platteville specimen figured by Whitfield under *Oncoceras pandion*. It is characterized chiefly by its lateral compression, and the fact that the living chamber is not so strongly contracted toward the aperture.

41. BELOITOCERAS PLEBEIUM HALL

PLATE XXXVI, FIGS. 4A, B, 3A, B; PLATE XLI, FIGS. 5A, B

Oncoceras plebeium Hall; Rep. Superintendent Geol. Surv. Wisconsin, 1861, p. 44

Oncoceras plebeium Whitfield, Mem. Amer. Mus. Nat. Hist., vol. 1, pt. 2, 1895, p. 68, pl. IX, figs. 16-19

The original description indicates that several specimens were at hand at the time of description of this species. Of these Whitfield figured three. The largest is selected as the type because it bears the small lozenge-shaped yellow label, and retains a remnant of the thin paper label which Hall used for indicating his types among the species described in 1861. Moreover, this specimen is the first one of the three figured by Whitfield.[38]

Selected type.—Specimen (Plate XXXVI, Figs. 4A, B; Plate XLI, Figs. 5A, B) consisting of the living chamber with 7 camerae still attached. Conch rather strongly curved lengthwise in a dorso-ventral plane; the radius of convex curvature of the ventral side, along the upper part of the phragmacone and along the living chamber, is 45 mm.; the radius of concave curvature of the dorsal side, along the upper part of the phragmacone, is 30 mm.; a very faint convexity extends from the base of the second camera below the living chamber upward along the greater part of the living chamber, but within 3 or 4 mm. from the aperture the dorsal outline is slightly concave again. The faint convexity along the lower part of the dorsal side of the liv-

[36] Clarke, John M., The Lower Silurian Cephalopoda of Minnesota; Minn. Geol. Survey, Final Rept., vol. 3, pt. 2, p. 799, pl. 58, figs. 4-6a, 1897.
[37] Idem. p. 799, pl. 58, figs. 7-9.
[38] Whitfield, R. P., Republication of descriptions of fossils from the Hall collection; Mem. Am. Mus. Nat. Hist., vol., 1, pl. 9, figs. 15, 16, 1895.

ing chamber is supposed to correspond to the much more pronounced gibbosity of *Oncoceras constrictum* Hall, but it is located farther up.

The dorso-ventral diameter enlarges from 19 mm., at the base of the specimen, to 22 mm. at the base of the living chamber, the latter being 19 mm. farther up along the ventral side of the conch. At mid-height of the living chamber this dorso-ventral diameter is still 22 mm., but at the constricted part, 3 mm. below the aperture, it is only 20 mm., enlarging slightly above this point. Since the specimen is a cast of the interior of the shell, the apparent enlargement of the living chamber near its aperture may be due chiefly to a thickening of the interior of the shell there, the exterior of the shell not showing any corresponding expansion.

The conch is strongly compressed laterally, the lateral diameter at the base of the specimen being 15 mm.; at the base of the living chamber it is 18 mm.; about 2 mm. above this base it is 18.5 mm.; and from this point upward it diminishes gradually, until 3 mm. below the aperture, at the constricted part, it is 15.5 mm.; above this constricted part it increases slightly. The broadest part of the cross-section of the conch is distinctly dorsad of its center, the ventral side being much more narrowly rounded than the dorsal one, especially toward the aperture, whose contour is distinctly oval in outline.

The sutures of the septa are directly transverse along the dorsal side of the phragmacone, and this direction is maintained along the dorso-lateral parts of the conch; but, on approaching the middle of the lateral sides, the sutures curve progressively more strongly upward, until they form an angle of about 75° with the ventral outline, when the cast of the interior of the phragmacone is viewed from one of the lateral sides. The result is the formation of distinct saddles along the ventral side of the conch. The number of camerae, in a length equal to the dorso-ventral diameter of the conch at the top of the series of camerae being counted, is 8, when the counting is done along the ventral side. When compared with the corresponding lateral diameter, this number of camerae is slightly greater than 6. The septa are only moderately concave. The exterior of the cast of the interior of the phragmacone is marked by faint traces of vertical ribs, most readily detected on the dorsal side of the cast.

The siphuncle is almost in contact with the ventral wall of the conch; it is moniliform in structure; its maximum diameter within the camerae is 2.2 mm., diminishing to 1.5 mm. at its passage through the septa.

Smaller specimen figured by Whitfield.—This specimen (Plate XXXVI, Figs. 3A, B) is illustrated by figures 18 and 19 among the series published by Whitfield. It consists of the living chamber with 9 camerae still attached. It is closely similar in form to the larger specimen figured by Whitfield, but its dorso-ventral diameter at the base of the living chamber is only 17 mm. instead of 22 mm., and its lateral diameter is largest (15.5 mm.) fully one-third of the height of the living chamber above its base, where the diameter is 14.5 mm. The phragmacone appears to enlarge more rapidly in size, and the concave curvature of the sutures of the septa along the middle of the lateral sides is much less conspicuous. On the contrary, these sutures rise slightly even along the dorso-lateral sides of the phragmacone and their rise is only moderately accentuated along the middle of the lateral sides, but they form about the same angle with the ventral outline of the phragmacone. In the smaller, as well as in the larger specimen here described, the sutures form progressively more acute angles on approaching the upper part of the phragmacone.

Phragmacone figured by Whitfield.—This specimen is illustrated by figure 17 of the series published by Whitfield. It apparently belonged to a mature individual, judging from the distinct shortening of the uppermost camera, compared with the camerae immediately beneath. Evidently, even the uppermost camera of the phragmacone is preserved. It is significant, therefore, that the dorso-ventral diameter at the top of the specimen is only 17 mm., in this respect agreeing more readily with that of the smaller specimen figured by Whitfield. The sutures of the septa rise even more strongly toward the ventral side of the conch. The height of the camerae is distinctly greater, 7 camerae occurring in a length equal to the dorso-ventral diameter, in place of 8, when this length is measured along the ventral side of the shell and the dorso-ventral diameter is measured at the top of the series of camerae being counted.

Other specimens.—The Hall collection at the American Museum of Natural History includes five specimens in addition to

those figured by Whitfield. Two of these retain enough of the living chamber and of the attached part of the phragmacone to be referred with confidence to *Oncoceras plebeium*. One of these has a dorso-ventral diameter of 17 mm. at the base of the living chamber, the other of 19.5 mm. A third specimen consists of a body chamber, expanding toward the aperture as in *Cyrtorizoceras minneapolis* (Clarke) and *Cyrtorizoceras scofieldi* (Clarke). Not enough remains of the other two specimens to make their relationship to *Oncoceras plebeium* certain.

Locality and horizon.—Described from the "Buff limestone of the Trenton limestone group, at Beloit," Wisconsin. According to Bassler's Bibliographic Index, the horizon of this species is the Platteville member of the Black River.

Types, No. 996, American Museum of Natural History, in New York City.

Margin of the aperture.—One of the specimens in the American Museum of Natural History apparently presents features both of the exterior and of the interior of the upper part of the shell, but its chief interest lies in the fact that it retains a sharp outline of the margin of the aperture. This margin is most elevated along the middle of the lateral sides, and from this point it slopes slightly downward both toward the dorsal and toward the ventral side; however, the slope toward the ventral side of the conch is slightly greater than that toward the dorsal side, compared with the direction of the central axis of the living chamber. The hyponomic sinus evidently is very shallow. When viewed from above, however, the aperture contracted distinctly ventrad of its center, as in the type of *Oncoceras plebeium*.

Along the dorsal half of the specimen, the living chamber is contracted slightly but distinctly at a level about 5 or 6 mm. below the margin of the aperture. Toward the ventral side this contraction is scarcely 4 mm. from the margin of the aperture. Above this point of contraction the specimen retains about the same dimensions as far as the aperture. Since no trace of the septa is shown by the specimen, this contraction appears to be a feature of the exterior surface of the shell as well as of its interior, but ordinarily it would be regarded as characteristic of the interior of the living chamber alone, due to a thickening of the interior of the shell along the line indicated.

Judging from the contours of the specimen, the height of the

living chamber, along the middle of its lateral sides, is 20 mm.; and the dorso-ventral diameter at this point is 20 mm., diminishing to 19 mm. at the aperture.

This specimen is numbered 999B in the American Museum of Natural History, and is incorrectly associated under this number with *Oncoceras lycus*. It was obtained at Beloit, Wisconsin, at the same locality and horizon with the type of *Oncoceras plebeium*.

Oncoceras lycum Clarke[39] appears to be closely similar to *Oncoceras plebeium*, as far as may be determined from the figures. The increase in concave curvature of the dorsal side near the aperture and the straightening of the shell along the middle and lower part of the dorsal side of the living chamber is characteristic; the distance between the septa is similar; also the course of the sutures.

Cyrtoceras houghtoni Clarke[40] may be the same as the smaller specimen figured by Whitfield under *Oncoceras plebeium*. In both figures 13 and 15 there is apparently a very faint trace of a straightening or swelling along the lower two-thirds of the living chamber. Moreover, the sutures of the septa are about the same distance apart. The extreme lateral compression of the conch shown by figures 14 and 14a is regarded as due to fossilization, and not as characteristic of the shell in its original state.

42. BELOITOCERAS LYCUM (HALL)

PLATE XXXVI, FIGS. 2 A, B

Oncoceras lycum Hall; Rep. Superintendent Geol. Surv. Wisconsin, 1861, p. 45

Onoceras lycus Whitfield; Mem. Amer. Mus. Nat. Hist., vol. 1, pt. 2, 1895, p. 69, pl. IX, figs. 13, 14

Specimen consisting of a living chamber with 10 camerae still attached. Conch moderately curved lengthwise in a dorso-ventral plane; the radius of convex curvature of the ventral side of the phragmacone and of the lower half of the living chamber is 55 mm.; the radius of concave curvature of the dorsal side of the phragmacone is 40 mm. For a distance of 5 or 6 mm. below the base of the living chamber, and for an equal distance above the base, the dorsal outline of the conch is nearly straight lengthwise, suggesting a slight gibbosity of the dorsal outline of the lower

[39] Clarke, op. cit., p. 799, pl. 58, figs. 1-3a.
[40] Idem. p. 807, pl. 59, figs. 12-15.

half of the living chamber, followed by a slightly concave lengthwise curvature along the upper half of this living chamber, in a normal shell, somewhat as in *Oncoceras plebeium* Hall, from the same locality and horizon as the type of *Oncoceras lycum*.

The specimen is a cast of the interior of the conch. In this specimen the cast of the interior of the living chamber is contracted abruptly and strongly near mid-height. The contraction begins about 8 mm. above the base of this chamber and reaches its maximum at 10 mm. above this base; above this level of maximum contraction the cast expands evenly as far as the aperture. The dorso-ventral diameter of this cast, at the base of the living chamber, is 17 mm.; 8 mm. above the base it is 18 mm.; at the most narrowly contracted part of the chamber it is 15 mm.; and from this point of greatest contraction the cast of the interior enlarges evenly to approximately 17 mm. at the aperture, as far as can be determined from that part of the aperture which is preserved. This abrupt and strong contraction of the cast of the interior of the living chamber may not be indicative of any corresponding contraction of the exterior of the shell. On the contrary, it may be confined to its interior, and may be due to a very gerontic thickening of the interior of the living chamber, at mid-height, in case of some individual specimen; or, the animal after death may have contracted along the upper half of the living chamber, as appears to have been the case not infrequently in some Silurian Poterioceroids. The symmetrical contraction of this cast favors the first one of these views, namely that the walls of the conch were thickened above mid-height by a gerontic deposit upon their interior surface. If this was the case, then the exterior of the living chamber may have contracted toward its aperture very much as in *Oncoceras plebeium*, from the same horizon and locality. In fact, *Oncoceras lycum* may have differed from the type of *Oncoceras plebeium* chiefly in its smaller curvature lengthwise, and in the greater height of the camerae.

The phragmacone enlarges from a dorso-ventral diameter of 11 mm. at its base to 17 mm. at its top; the length of the phragmacone, measured along its ventral side, is 22 mm. According to this rate of tapering, the total length of the conch probably did not exceed 75 mm., when measured along its ventral side. The lateral diameter of the specimen at its base is 9.8 mm., and

at the top of the phragmacone it is 15.5 mm., indicating a moderate lateral compression of the conch. There is a slight tendency toward angularity in the cross-section of the conch, along the median line of its ventral side, especially toward the top of the phragmacone.

Counting along the ventral side of the conch, there are 7 camerae in a length equal to the dorso-ventral diameter of the conch at the top of the series of camerae being counted. The sutures of the septa are directly transverse on the dorsal and dorso-lateral sides of the conch, but they curve upward on approaching the ventral side of the conch, producing low ventral saddles.

The siphuncle is close to the ventral wall of the conch. At the base of the specimen, the diameter of the siphuncle, where it passes through the septum, is slightly over 1 mm. Very faint vertical ribs, easily escaping attention, mark the cast of the interior of the phragmacone.

Locality and horizon.—Described from the "Buff limestone of the Trenton limestone group;" referred by Bassler, in his Bibliographic Index, to the Platteville member of the Black River. The type specimen is labelled as coming from Beloit, Wisconsin.

Holotype.—No. 999, American Museum of Natural History, in New York City.

Remarks.—The appearance of greater height in the camerae is due chiefly to the small curvature of the conch lengthwise, owing to which the septa are less closely crowded together on the dorsal side of the conch, measuring only 5.5 camerae in a length of 10 mm., instead of 8 camerae as in the smaller specimen of *Oncoceras plebeium* figured by Whitfield.

43. WESTENOCERAS GEN. NOV.

Genotype: **Cyrtoceras manitobense** Whiteaves. Trans. Royal Soc. Canada, vol. 7, sec. 4, 1890, p. 80, pl. 13, figs. 3-5; pl. 15, fig. 4

Conch slender, sub-fusiform, nearly straight along the dorsal side, except at the aperture, but distinctly curved along the ventral side. Aperture oblique, inclining downward from the ventral toward the dorsal side. Sutures of the septa curving strongly downward laterally, but rising dorsally and ventrally into distinct saddles, which rise higher on the ventral than on the dorsal side. Siphuncle nearer the ventral than the dorsal side, described as "nearly cylindrical, but very slightly expanded between the septa and as slightly contracted where it intersects

them." Further study of typical specimens is necessary to determine the exact structure of the siphuncle.

44. POTERIOCERAS McCOY

Genotype: **Orthoceras fusiforme** Sowerby. See Foord, Carb. Foss, Ireland, pl. 15

The name *Poterioceras* was proposed by McCoy for certain Carboniferous species, the generic description being: "Shell fusiform. Mouth contracted. Siphuncle dilated between the chambers, excentric." Blake states that the diagram accompanying this description is not justified by any known species, and represents the aperture as very small but simple.

The species mentioned first in the body of the text is *Poterioceras fusiform* (Sowerby)[41] from Boland, Kildare. This was founded on a specimen 6 inches long, 6 lines wide at the small end, one inch and 7 lines wide at its largest diameter, and 9 lines wide at the aperture.

A study of a specimen from Kildare, Ireland, numbered 2177 in the Museum of Comparative Zoology at Harvard University, (Plate XLI, Figs. 1A, B) indicates the following characteristics:

Conch fusiform, curved lengthwise, with the ventral side convex, and the dorsal side concave, except along the upper part of the phragmacone and the lower part of the living chamber along the dorsal side, where the outline is distinctly convex or gibbous. Toward the base of the living chamber the sutures rise from the ventral toward the dorsal side of the conch. The siphuncle is located a short distance ventrad from the center of the conch. The septal necks are short and curve distinctly downward and outward. The connecting rings are elongate elliptical in outline. The aperture appears to have been circular in outline and its margin directly transverse. There may have been a shallow hyponomic sinus, but this is not indicated by the specimen at hand. Conchs of this type do not occur in Silurian or Ordovician strata.

Poterioceras fusiform (Sowerby) was figured by Foord[42] and one of his illustrations is reproduced herewith (Plate XL, fig. 2). *Poterioceras latiseptum* Foord[43] likewise shows the rise of the sutures of the septa from the ventral toward the dorsal side of

[41] Sowerby, Mineral Conchology, pl. 588, figs. 1, 2.
[42] Foord, Carb. Ceph. Ireland, 1897, pl. 15.
[43] Idem, pl. 16.

the conch. The siphuncle is between the center of the conch and its ventral wall, and the segments of this siphuncle are more nearly circular or slightly elongate in outline. *Poterioceras ventricosum* McCoy apparently presents a different contour from typical *Poterioceras*, as based on *fusiforme*.

45. AMPHICYRTOCERAS GEN. NOV.

Genotype: **Cyrtoceras orcas** Hall

Conch subfusiform, but curved lengthwise and depressed dorsoventrally. The ventral side of the conch is curved convexly, and the dorsal side is concave except toward the upper part of the phragmacone and the lower part of the living chamber, along which it is gently convex or distinctly gibbous. The living chamber contracts toward the aperture, and the margin of the latter is nearly directly transverse dorsally and laterally, but curves gently downward toward the median line of the ventral side, where a shallow hyponomic sinus is located. The siphuncle is near the ventral wall of the conch, but not in actual contact with it. The septal necks curve distinctly downward, and the connecting rings tend to be almost cylindrical in form, except at their upper and lower extremities, where they contract abruptly.

The genotype, *Cyrtoceras orcas* Hall, is relatively common in the Racine member of the Niagaran, at Racine, Waukesha, and elsewhere in Wisconsin. *Cyrtoceras laterale* Hall, from the same area and horizon, is congeneric. *Oncoceras pettiti* Billings, and possibly *Oncoceras thales* Billings from the Niagaran of Ontario also belong here. *Strepoceras janus* Billings and *Streptoceras heros* Billings differ in having a protruding hyponomic sinus, like an incipient lip.

46. AMPHICYRTOCERAS ORCAS (HALL)

PLATE XXIX, FIGS. 1 A, B, C

Cyrtoceras orcas Hall; Rep. Superintendent Geol. Surv. Wisconsin, 1862, p. 43
Oncoceras orcas Hall; 20th Rep. New York State Cab. Nat. Hist., 1868, p. 350, pl. 17, figs. 1, 2

The type of this species, measured along the curvature of its ventral side, is 143 mm. long. The living chamber appears to occupy 57 mm. of this length, but there is a possibility that one camera, whose upper septum is not exposed, is included in this measurement. The upper three exposed camerae occupy a length of 30 mm.; the next three, 29 mm.; and the lowest three,

27 mm. At the uppermost exposed septum, the greatest width of the phragmacone is 55 mm., but 10 mm. farther up the width of the living chamber is 1 mm. greater. The smallest septum, at the base of the specimen, has an estimated width of 25 mm.; from this point the conch widens along the entire length of the phragmacone. The living chamber narrows to 40 mm. at the aperture. The general aspect, viewed from the ventral side, is subfusiform. The conch is depressed dorso-ventrally. At the top of the phragmacone the ratio of the lateral to the dorso-ventral diameter is 55 to 50 mm. Toward the lower end of the phragmacone the cross-section becomes more nearly circular.

The lengthwise curvature of the ventral side of the conch is convex, with a radius of 105 mm. The lengthwise concave curvature of most of the dorsal side of the phragmacone has a radius of 90 mm., until within a short distance of the base of the living chamber. At this upper level the general aspect of the shell is tumid or swollen, the dorsal outline changing from concave to slightly convex. In a general way, this convexity of outline extends from the base of the third camera beneath the living chamber to mid-height of the latter, above which the dorsal outline is slightly concave again. The contraction of the living chamber, both laterally and dorso-ventrally, is quite regular as far as the aperture, with a very faint decrease in the rate of contraction within 5 mm. of the margin of this aperture, in the type, but not in other specimens of this species.

Septa with a concavity of 10 mm. occur at a point where the width of the conch, not the type, is 54 mm. The sutures of the septa appear to be nearly straight on the dorsal and lateral sides, but incline slightly downward toward the ventral side. If there is a tendency toward a slightly concave curvature of the sutures on the ventral side, this is not known definitely, although suspected from the inclination of the three septa seen on the ventral side of the type, where part of the shell has spalled off. In analogy with the species originally described as *Cyrtoceras laterale*, the siphuncle is located on the ventral side of the conch, about 3 mm. distant from the ventral wall.

The surface of the shell is crossed by low, broad, transverse bands or lines of elevation of which 12 occur in a length of 20 mm. These bands are deflected downward on the ventral side of the more inflated part of the conch for a distance of 3 mm.

and for a width of 25 mm., thus locating the hyponomic sinus at earlier stages of growth. A partially exfoliated conch, numbered 3195 at the Public Museum of Milwaukee, Wisconsin, displays vertical bands and striae in addition to the transverse bands.

Location and horizon.—In the original description of the species, Racine is mentioned first as a source of material, but the type is from Waukesha, Wisconsin. It is numbered 2112 in the American Museum of Natural History.

Remarks.—In the 20th Report of the New York State Cabinet of Natural History, cited above, the generic reference of this species is changed from *Cyrtoceras* to *Oncoceras*, but the type of the latter is a Trenton form, compressed laterally, not depressed dorso-ventrally as in the Racine species here described. Moreover, the segments of its siphuncle are rather narrowly fusiform, instead of cylindrical or barrel-shaped in outline.

Numerous specimens of *Amphicyrtoceras orcas* are in the Greene Museum at Milwaukee-Downer College, in Milwaukee, Wisconsin.

47. AMPHICYRTOCERAS LATERALE (HALL)

PLATE XXX, FIGS. 1 A-D, 2 A, B

Cyrtoceras laterale Hall; 20th Rep. New York State Cab. Nat. Hist., 1868, p. 357, pl. 18, figs. 4, 5, 6

Type.—Cyrtoceracone comparatively little curved. The lengthwise dorsal outline is nearly straight. The corresponding ventral outline is curved lengthwise with a radius of 150 mm. The specimen consists of a phragmacone, with only the basal part of the living chamber still attached. The lateral diameter of the phragmacone increases rapidly from 17 mm. at the base to 37 mm. at the top of the eighth camera from the smaller end. From this point upward, for a distance of 4 camerae, the lateral diameter remains about the same. The contraction near the base of the living chamber is slight. At the smaller end of the phragmacone the transverse section is nearly circular, the dorso-ventral diameter being 17 mm. Farther up, the conch rapidly becomes depressed dorso-ventrally. At the top of the eighth camera, the cross-section is transversely elliptical, the dorso-ventral diameter being 28 mm. The curvature of the conch in a lat-

eral direction is slightly greater on the ventral than on the dorsal side.

The sutures of the septa curve slightly downward along the median parts of the ventral side, especially near mid-length of the phragmacone. The location of the siphuncle at the smaller end of the specimen is indicated by a small circle, 1.5 mm. in diameter, with its center 3 mm. from the ventral wall of the conch. Very faint, low, broad, almost obsolete vertical ribs, about 7 in a width of 20 mm., are seen on casts of the interior of the conch.

Locality and horizon.—From Racine, Wisconsin, in the Racine member of the Niagaran. Specimen numbered 2119 in the American Museum of Natural History.

Milwaukee Museum specimen.—Another specimen, numbered 634 in the Public Museum of Milwaukee, Wisconsin, consists of the living chamber and 6 upper camerae. The maximum width, 49 mm., occurs at the first camera beneath the living chamber. The contraction of the upper part of the living chamber begins 8 mm. above the base of the latter. The height of this living chamber is 44 mm. It contracts from a width of 49 mm. at its base to an estimated width of 39 mm. at its top. The corresponding dorso-ventral contraction is estimated from 44 mm. at its base to 35 mm. at its top. The phragmacone is distinctly, though gently, concave along its dorsal lengthwise outline. The sutures of the upper septa slant slightly downward toward the ventral side, and curve more strongly downward along the median part of the latter, for a vertical distance of 3 or 4 mm. and for a width of 25 mm. Farther down, the curvature of the sutures becomes less conspicuous. The siphuncle is situated about 3 mm. from the ventral wall of the conch. Its segments are somewhere between short cylindrical and barrel-shaped in vertical outline. At the uppermost camera its diameter is almost 6 mm., diminishing at its passage through the septum to 3 mm. The septal necks are short, about half a millimeter in length. The cast of the interior of the phragmacone is marked by nearly obsolete vertical ribs, extending upward along the lower half of the living chamber, but becoming very indistinct there.

Remarks.—*Amphicyrtoceras laterale* evidently is closely related to *Amphicyrtoceras orcas*, and there is a possibility of their being specifically identical. At present, the vertical ribbing of

the casts of the interior of *Amphicytoceras laterale*, and a difference in the vertical outline of the upper part of the ventral side of the living chamber, appear characteristic.

48. AMPHICYRTOCERAS TANTALUM SP. NOV.
PLATE XXIX, FIGS. 2 A, B, C

Conch small, with its maximum lateral diameter, 27.5 mm., along the second camera beneath the living chamber. Above this point the lateral diameter shortens, at first slowly and then more rapidly for a height of 15 mm., where its lateral diameter is 19 mm. Above this the conch rises at least 8 mm. as a narrow neck, terminating in the specimen at hand at about the level of the aperture. The rate of enlargement of the lower part of the phragmacone is rapid. The conch is strongly depressed dorso-ventrally, the ratio of the dorso-ventral to the lateral diameter being as 24 to 27.5 mm. at the widest part of the conch. At the aperture the corresponding ratio is as 15.5 to 19 mm. At the base of the specimen it is as 14 to 16 mm. A little over 8 camerae occur in a length equal to the maximum width of the conch. The sutures are nearly directly transverse, but sag down a little on the ventral side of the conch. The septa are very moderately concave, and the siphuncle appears to occur one-third of the dorso-ventral diameter from the ventral side. Its passage through the septum at the base of the specimen is small, and the form and structure of its segments are unknown.

Locality and horizon.—From the strata regarded as approximately equivalent to the Cedarville dolomite, at the abandoned railroad quarry in the northeastern part of Hillsboro, Ohio. Found by Henry Pavey.

Remarks.—*Amphicyrtoceras tantalum* is characterized by its small size, the rapid constriction of the living chamber, and the elongation of the upper part of this chamber into a neck.

MONOCYRTOCERAS GEN. NOV.
Genotype: **Monocyrtoceras lentidilatatum** Foerste

Conch related to *Amphicyrtoceras*, but enlarging at a much smaller rate; there is no dorsal gibbosity; and the siphuncle is much nearer the center of the conch, being only a short distance ventrad of the latter.

49. MONOCYRTOCERAS LENTIDILATATUM SP. NOV.

PLATE XXXVII, FIG. 1; PLATE XXXVIII, FIG. 1; PLATE XXXIX, FIG. 1; PLATE XL, FIGS. 1A, B; PLATE XLI, FIGS. 3A, B

Greenfield specimen.—Specimen consisting of the lower part of a living chamber with 11 camerae still attached. A twelfth camera is represented by the cast of the interior of one of the segments of the siphuncle, at the base of the specimen. Conch distinctly curved lengthwise, the radius of curvature of the convex or ventral side being about 450 mm., and that of the concave or dorsal side about the same. The conch is distinctly compressed dorso-ventrally. The dorso-ventral diameter at the base of the living chamber is 66 mm., the lateral diameter being estimated at 75 mm. The lateral diameter enlarges from 60 mm. at the base of the specimen to 75 mm. at the base of the living chamber, the intervening distance being 125 mm., measured along the ventral side of the conch, but most of this enlargement takes place along the lower 5 camerae retained by the specimen. The living chamber contracts slightly laterally, in an upward direction. The dorso-ventral diameter increases from 53 mm. at the base to 60 mm., 5 camerae farther up, and to 66 mm. at the base of the living chamber. Apparently it continues to enlarge for 40 mm. above the suture outlining the base of the living chamber. About 6 camerae occur at the top of the phragmacone in a length equal to the lateral diameter of the conch, but the uppermost two camerae shorten rapidly, indicating that the specimen was fully mature. In descending order, the uppermost camera has a length of 6 mm., the next beneath of 8 mm., and the next 7 or 8 camerae of 10 or 11 mm.

The sutures of the septa curve downward moderately both dorsally and ventrally, and rise laterally to a corresponding degree. The concavity of the septum at the base of the specimen equals 13 mm. When the dorso-ventral diameter is 53 mm., the center of the siphuncle is 21 mm., or two-fifths of the dorso-ventral diameter, from the ventral wall of the conch. The lateral diameter of the siphuncle, where in contact with the septum beneath, is 13 mm., and it contracts here suddenly to 7 mm. at the beginning of the septal neck. The lower margin of this neck flares out strongly, the length of the neck being slightly over 1 mm. The sides of the segments of the siphuncle, within the walls of the camerae, present straight profiles, the segments hav-

ing the form of tubes connected by short central passages of much smaller diameter. In form, the siphuncle closely resembles that of *Amphicyrtoceras orcas* (Hall), from the Racine of Wisconsin, but the conch is much more elongate.

The surface of the shell is crossed by transverse, and rather faint, raised lines or striae. The surface of the cast of the interior of the specimen is faintly ribbed vertically, as in some specimens of *Amphicyrtoceras orcas*.

Locality and horizon.—Greenfield, Wisconsin; in the Racine member of the Niagaran. No. 2315, in the Museum of Comparative Zoology, at Harvard University.

Living chambers from Wauwatosa.—With the specimen described above, consisting chiefly of the phragmacone, are correlated two living chambers, found at another locality. These living chambers agree fairly well in size and cross-section with the remnant of the living chamber preserved in the preceding specimen. Moreover, these living chambers are of such length, and have such a slow rate of contraction toward the aperture as to suggest that they belong to a slowly enlarging species, and *Amphicyrtoceras lentidilatatum* is such a species.

At the base of one of the living chambers, the dorso-ventral diameter is 70 mm., and the lateral diameter is 78 mm. Along the dorsal side of the living chamber, the margin of the aperture rises 78 mm. above the suture at its base. Here the lateral diameter is 69 mm., and the dorso-ventral diameter is estimated at 63 mm. Distinct contraction of the living chamber begins about 30 to 35 mm. above its base. At the base of the cast of the interior, there is a transverse groove 6 mm. high, locating the annular attachment ring following the inner wall of the chamber. This groove is crossed by 10 low vertical ribs in a width of 35 mm., their upward continuations being faintly visible for some distance above the transverse groove. Laterally this groove makes an angle of 10° with a horizontal plane, sloping from the dorsal side downward toward the ventral. The margin of the aperture forms a broad shallow lobe on the ventral side; it rises laterally and ventro-laterally, and curves distinctly, though only moderately, downward along the median part of the ventral side, thus locating the hyponomic sinus. Toward the upper part of the living chamber, the median part of the ventral side extends slightly outward beyond the general trans-

49. MONOCYRTOCERAS LENTIDILATATUM SP. NOV.

PLATE XXXVII, FIG. 1; PLATE XXXVIII, FIG. 1; PLATE XXXIX, FIG. 1; PLATE XL, FIGS. 1A, B; PLATE XLI, FIGS. 3A, B

Greenfield specimen.—Specimen consisting of the lower part of a living chamber with 11 camerae still attached. A twelfth camera is represented by the cast of the interior of one of the segments of the siphuncle, at the base of the specimen. Conch distinctly curved lengthwise, the radius of curvature of the convex or ventral side being about 450 mm., and that of the concave or dorsal side about the same. The conch is distinctly compressed dorso-ventrally. The dorso-ventral diameter at the base of the living chamber is 66 mm., the lateral diameter being estimated at 75 mm. The lateral diameter enlarges from 60 mm. at the base of the specimen to 75 mm. at the base of the living chamber, the intervening distance being 125 mm., measured along the ventral side of the conch, but most of this enlargement takes place along the lower 5 camerae retained by the specimen. The living chamber contracts slightly laterally, in an upward direction. The dorso-ventral diameter increases from 53 mm. at the base to 60 mm., 5 camerae farther up, and to 66 mm. at the base of the living chamber. Apparently it continues to enlarge for 40 mm. above the suture outlining the base of the living chamber. About 6 camerae occur at the top of the phragmacone in a length equal to the lateral diameter of the conch, but the uppermost two camerae shorten rapidly, indicating that the specimen was fully mature. In descending order, the uppermost camera has a length of 6 mm., the next beneath of 8 mm., and the next 7 or 8 camerae of 10 or 11 mm.

The sutures of the septa curve downward moderately both dorsally and ventrally, and rise laterally to a corresponding degree. The concavity of the septum at the base of the specimen equals 13 mm. When the dorso-ventral diameter is 53 mm., the center of the siphuncle is 21 mm., or two-fifths of the dorso-ventral diameter, from the ventral wall of the conch. The lateral diameter of the siphuncle, where in contact with the septum beneath, is 13 mm., and it contracts here suddenly to 7 mm. at the beginning of the septal neck. The lower margin of this neck flares out strongly, the length of the neck being slightly over 1 mm. The sides of the segments of the siphuncle, within the walls of the camerae, present straight profiles, the segments hav-

ing the form of tubes connected by short central passages of much smaller diameter. In form, the siphuncle closely resembles that of *Amphicyrtoceras orcas* (Hall), from the Racine of Wisconsin, but the conch is much more elongate.

The surface of the shell is crossed by transverse, and rather faint, raised lines or striae. The surface of the cast of the interior of the specimen is faintly ribbed vertically, as in some specimens of *Amphicyrtoceras orcas.*

Locality and horizon.—Greenfield, Wisconsin; in the Racine member of the Niagaran. No. 2315, in the Museum of Comparative Zoology, at Harvard University.

Living chambers from Wauwatosa.—With the specimen described above, consisting chiefly of the phragmacone, are correlated two living chambers, found at another locality. These living chambers agree fairly well in size and cross-section with the remnant of the living chamber preserved in the preceding specimen. Moreover, these living chambers are of such length, and have such a slow rate of contraction toward the aperture as to suggest that they belong to a slowly enlarging species, and *Amphicyrtoceras lentidilatatum* is such a species.

At the base of one of the living chambers, the dorso-ventral diameter is 70 mm., and the lateral diameter is 78 mm. Along the dorsal side of the living chamber, the margin of the aperture rises 78 mm. above the suture at its base. Here the lateral diameter is 69 mm., and the dorso-ventral diameter is estimated at 63 mm. Distinct contraction of the living chamber begins about 30 to 35 mm. above its base. At the base of the cast of the interior, there is a transverse groove 6 mm. high, locating the annular attachment ring following the inner wall of the chamber. This groove is crossed by 10 low vertical ribs in a width of 35 mm., their upward continuations being faintly visible for some distance above the transverse groove. Laterally this groove makes an angle of 10° with a horizontal plane, sloping from the dorsal side downward toward the ventral. The margin of the aperture forms a broad shallow lobe on the ventral side; it rises laterally and ventro-laterally, and curves distinctly, though only moderately, downward along the median part of the ventral side, thus locating the hyponomic sinus. Toward the upper part of the living chamber, the median part of the ventral side extends slightly outward beyond the general trans-

verse curvature of the conch, but so slight is this outward curvature that it is likely to escape attention. An accentuation of this outward curvature would lead to forms such as those included under *Streptoceras*. Within 5 or 10 mm. from the aperture the dorsal and ventral walls of the cast of the interior of the living chamber curve slightly outward. The surface of the shell is striated faintly in a transverse direction, and weathered parts of the surface show very faint vertical striae.

Location and horizon.—Schoonmaker's quarry, at Wauwatosa, Wisconsin, in the Racine member of the Niagaran. No. 2312, in the Museum of Comparative Zoology, at Harvard University.

Flattened Wauwatosa phragmacone.—The specimen consists of 15 camerae, no part of the living chamber being retained. It is of interest chiefly because it gives some idea of the rate of increase in the size of the conch, notwithstanding the fact that it is strongly compressed dorso-ventrally, evidently during fossilization. This flattening probably is due to vertical compression of the enclosing strata. There is no evidence that the width of the specimen was increased by this flattening. The height of the camerae agrees very well with that of the camerae in the type specimen from Greenfield, Wisconsin.

Specimen No. 2301, in the Museum of Comparative Zoology, at Harvard University. From Wauwatosa, Wisconsin.

50. DIESTOCERAS GEN. NOV.

Genotype: **Gomphoceras indianense** Miller and Faber

Conch relatively erect, practically without any lengthwise curvature, though possibly gently curved in its initial stages of growth. There is only a slight difference in the lengthwise curvature of the dorsal and ventral sides of the upper part of the conch. The siphuncle is located close to the ventral wall, and the segments are so low and broad as to appear nummuloidal. The walls of the living chamber converge toward the aperture, but the latter is much less contracted than in *Gomphoceras*. On the contrary, the aperture remains relatively wide open, with only a moderate angularity on the ventral side, along the hyponomic sinus. The hyponomic sinus is relatively shallow and does not form a lobe distinct from the remainder of the aperture.

Gomphoceras indianense Miller and Faber is selected as the genotype, because this species is by far the most abundant, at

least in southwestern Ohio. *Gomphoceras eos* and *Gomphoceras obesum* are congeneric. *Poterioceras apertum* Whiteaves, *P. nobile* Whiteaves, and possibly *P. gracile* Whiteaves, also belong here. *Oncoceras alceus* Hall is another species.

51. DIESTOCERAS INDIANENSE (MILLER AND FABER)

PLATE XXV, FIGS. 1A, B; PLATE XXVI, FIGS. 1A, B, 2A, B; PLATE XXVII, FIG. 2

Gomphoceras indianense Miller and Faber, Jour. Cincinnati Soc. Nat. Hist., vol. 17, 1894, p. 137, pl. 7, figs. 3-5

Type.—Three specimens were collected by Faber in the upper part of the Richmond at Versailles, Indiana, and one was figured. The siphuncle was described as marginal, located on the ventral side of the conch, and abruptly expanded within the camerae to two and a half or three times its diameter at the septa.

Oxford specimens.—Conch (Plate XXV, Figs. 1A, B) relatively short, rapidly expanding along the lower part of the phragmacone, attaining its largest diameter at the base of the living chamber, distinctly contracting toward the aperture. In specimens retaining about 10 of the upper camerae of the phragmacone, the total length of these camerae along the dorsal side of the conch is a little greater than their total length along the ventral side, and the sutures of the septa rise slightly higher along the dorsal side, especially toward the living chamber. The vertical axis of the conch is nearly straight, but there is a faint tendency toward a lengthwise concave curvature along the ventral side. From this it is assumed that the location of the siphuncle is endogastric. The conch is slightly compressed laterally. In the specimen which seems least flattened by lateral pressure, the dorso-ventral diameter at the base of the living chamber is 63 mm., and the lateral diameter is 58 mm. At the base of the specimen, 46 mm. farther down, the cross-section is virtually circular, and about 34 mm. in diameter. Two very short camerae at the top of the phragmacone indicate that this specimen had reached full maturity. The living chamber is 38 mm. in height. The margin of the aperture is nearly directly transverse on its dorsal and lateral sides, but curves distinctly downward ventrally, forming a relatively shallow V-shaped hyponomic sinus. Possibly the margin of this aperture inclines slightly downward toward the dorsal side also, but this cannot be determined definitely from the specimen at hand. The lateral diameter of the

aperture is 39 mm.; its dorso-ventral diameter may be slightly greater. Its general form is circular, but along its ventral margin it is distinctly angular, though the angularity still is rounded. The margin of the aperture curves more or less horizontally inward for a distance of 3 or 4 mm.; perhaps less toward the ventral angularity. At this angularity the margin of the aperture curves downward, forming the hyponomic sinus.

In a second specimen, (Plate XXVI, Figs. 1A, B) from the same locality and horizon, the specimen is more compressed laterally, probably by pressure during fossilization. The lengthwise ventral outline is more convex. The aperture is well exposed, including the hyponomic sinus, but it also is compressed laterally.

The surface of casts of the interior of the conch usually is faintly ribbed vertically along the phragmacone. The surface of the shell is crossed transversely by low broad lines of elevation of variable strength, representing successive stages of growth. These serve to locate the ventral side of the conch, where they curve distinctly downward.

At the base of the eighth camera below the living chamber of one specimen, where in the present flattened condition of the specimen the diameters at right angles to each other are 42 and 37 mm., the maximum diameter of the siphuncle is 8.5 mm. and its passage through the septum is 5.5 mm. in diameter. At its contact with the overlying septum, the exposed segment of the siphuncle is in contact with the latter over its entire width, forming a circular area of contact, which is penetrated by the passage of the siphuncle through the septum in a strongly excentric position, its ventral margin being less than 1 mm. from the ventral margin of the segment. The ventral side of the segment is curved obliquely, in a direction approximately parallel to the ventral wall of the conch.

Locality and horizon.—Little Four Mile creek, near Oxford, Ohio; in the lower part of the Whitewater member of the Richmond formation. In the collection of Prof. W. H. Shideler, at Miami University.

Faber specimen.—A vertical section, in a dorso-ventral direction, through a specimen (Plate XXVI, Figs. 2A, B) collected by Mr. C. L. Faber at the same horizon on Little Four Mile creek, exposes the siphuncle sufficiently to indicate its relative

size, and the convexity of the vertical outlines of its segments; but the siphuncle has broken loose from the septa, and the structure of the siphuncle can not be determined in a satisfactory manner.

Saluda and Elkhorn specimens.—Specimens from the Saluda and Elkhorn members of the Richmond are in the collection of Prof. W. H. Shideler. These specimens evidently are congeneric with *Diestoceras indianense*, but not enough of the conch is preserved to make certain that they belong to the same species. One of these Salula specimens (Plate XXVII, Fig. 2) preserves the surface striae very well.

52. DIESTOCERAS EOS (HALL AND WHITFIELD)
PLATE XXVIII, FIGS. 1A, B

Gomphoceras eos Hall and Whitfield; Geol. Surv. Ohio, Pal., vol. 2, 1875, p. 100, pl. 3, fig. 5

Type.—Specimen 112 mm. in length; of this length 65 mm. belongs to the living chamber, 36 mm. belong to that part of the phragmacone which occurs between the base of the living chamber and the suture of the septum at the base of the specimen, and 11 mm. belongs to that part of the specimen which extends below the level of this suture in consequence of the downward curvature of the septum.

In its present condition the specimen is very much crushed laterally. The maximum expansion of the conch takes place about 23 mm. above the base of the living chamber. Here the dorso-ventral diameter is 81 mm., and the lateral diameter is 36 mm. At the base of the living chamber the corresponding diameters are 74 and 30 mm. At the base of the specimen these diameters are 44 mm. and 19 mm. The apical angle of that part of the phragmacone which is preserved approximates 45°. Above mid-height of the living chamber the latter contracts so that at 55 mm. above its base the dorso-ventral diameter is 62 mm. and the lateral diameter 21 mm. Above this level the living chamber continues to contract until its dorso-ventral diameter does not exceed 55 mm.

It is assumed, from the better preserved specimens of *Diestoceras indianense*, that the cross-section of *Diestoceras eos* originally was nearly circular, and that the outline of the aperture was nearly circular, with a moderate amount of angularity along the ventral margin. In conformity with other species referred

to *Diestoceras*, the side along which the septa are more approximate is regarded as ventral, while that along which they are more distant from each other is regarded as dorsal. Along the ventral side of the specimen 7 camerae occupy a length of 36 mm., while along the dorsal side the same 7 camerae occupy a length of 46 mm. The sutures of the septa rise slightly from the ventral toward the dorsal side of the conch. They are approximately straight. The septa may have been more deeply concave than in *Diestoceras indianense*, but the exposed septum at the base of the specimen may have secured its present form from crushing. No trace of the siphuncle is retained.

Locality and horizon.—From the vicinity of Dayton, Ohio, at the base of the Whitewater member of the Richmond formation. Specimen No. 3082, in the Geological Museum of Ohio State University. Along its upper margin the specimen contains a ventral valve of *Rhynchotrema capax*. Traces of an incrusting bryozoan occur on one side of the specimen.

Remarks.—Diestoceras eos differs from typical *Diestoceras indianense* in attaining the maximum enlargement of the conch at a point distinctly above the base of the living chamber. It is possible that the two species are identical, but, without a greater number of specimens at hand, it is not known within what limits *Diestoceras indianense* varies. The type of *Diestoceras eos* is so badly flattened as to leave elements of uncertainty, while that of *Diestoceras indianense* is much less distorted, and this species can be identified with confidence. For the present, at least, the latter is described as distinct.

53. DIESTOCERAS SHIDELERI SP. NOV.
PLATE XXVII, FIGS. 1A, B

Specimen presenting an elongate elliptical outline, consisting chiefly of a living chamber 55 to 58 mm. in height, with 4 camerae attached at its base. The specimen reaches its greatest transverse dimensions at mid-height of the living chamber. Here its lateral diameter is 67 mm., and its dorso-ventral diameter is 63.5 mm. At the base of the living chamber the corresponding diameters are 64 and 61 mm. respectively. At 50 mm. above the base of the living chamber the lateral walls curve strongly inward and then upward. Possibly this change in curvature indicates merely a thickened border in the interior of the chamber,

strengthening the margin of the aperture. Along the ventral side this margin appears to curve downward, forming a distinct hyponomic sinus.

The upper part of the phragmacone narrows so rapidly in an apicad direction that it is probable that the phragmacone was very short. The sutures of the septa rise distinctly from the ventral toward the dorsal side of the conch, and the height of the camerae enlarges in this direction. The siphuncle is exposed close to the ventral side of the conch. Within the lowest camera its diameter was at least 14 mm. The location of the passage of the siphuncle through the septum evidently was similar to that in *Diestoceras indianense*.

54. CYRTOGOMPHOCERAS GEN. NOV.

Genotype: **Oncoceras magnum** Whiteaves. Trans. Royal Soc. Canada, vol. 7, sec. 4, 1890, p. 79, pl. 15, fig. 1

Conch distinctly curved lengthwise, endogastric, and laterally compressed. The dorsal side is strongly convex, and the ventral outline of all but the uppermost part of the phragmacone is slightly concave, but along the top of the phragmacone and the adjacent part of the living chamber the ventral outline is distinctly gibbous. Conch compressed laterally. Sutures of the septa rising strongly from the ventral toward the dorsal side of the conch along the upper part of the phragmacone. Aperture correspondingly oblique, the living chamber being strongly contracted toward the latter. Siphuncle near the ventral wall of the conch, its segments strongly nummuloidal.

In addition to the genotype, *Oncoceras magnum* Whiteaves, this genus includes also *Oncoceras whiteavesii* Miller, a species originally described by Whiteaves as *Oncoceras gibbosum*.

Oncoceras intermedium Whiteaves is similar in having a strongly nummuloidal siphuncle near the concave or ventral side of the conch, and in having the septa rise strongly toward the dorsal side, but the conch is more slender, there is no gibbosity along the ventral side of the conch, and there is no evidence at present of the living chamber having a structure similar to that of typical *Cyrtogomphoceras*.

PLATE XXI

Fig. 1. *Endoceras proteiforme* Hall. Ventral side of the conch, showing downward flexure of the sutures of the septa, the siphuncle, and traces of the endocones, both at the top and near the middle of the specimen. Same specimen as fig. 4 on pl. 48 of Pal. New York, vol. 1, 1847. See also plate XXII, figs. 1A, 1B. Selected here as type of the species.

Fig. 2. *Endoceras proteiforme* Hall. Ventral side of a specimen, showing the downward curvature of the sutures of the septa, and the concave vertical outline of the septal necks of the siphuncle. Same specimen as fig. 1a on plate 49 of Pal. New York, vol. 1, 1847. See also fig 2 on pl. XXII, and fig. 2 on pl. XXIII.

Fig. 3. *Endoceras proteiforme* Hall. Ventral side of a specimen, showing the siphuncle. Same specimen as figs. 1b, 1c on pl. 49 of Pal. New York, vol. 1, 1847. See also figs. 1A, 1B on pl. XXIII.

All specimens figured on this plate are from Middleville, New York, in the Trenton limestone.

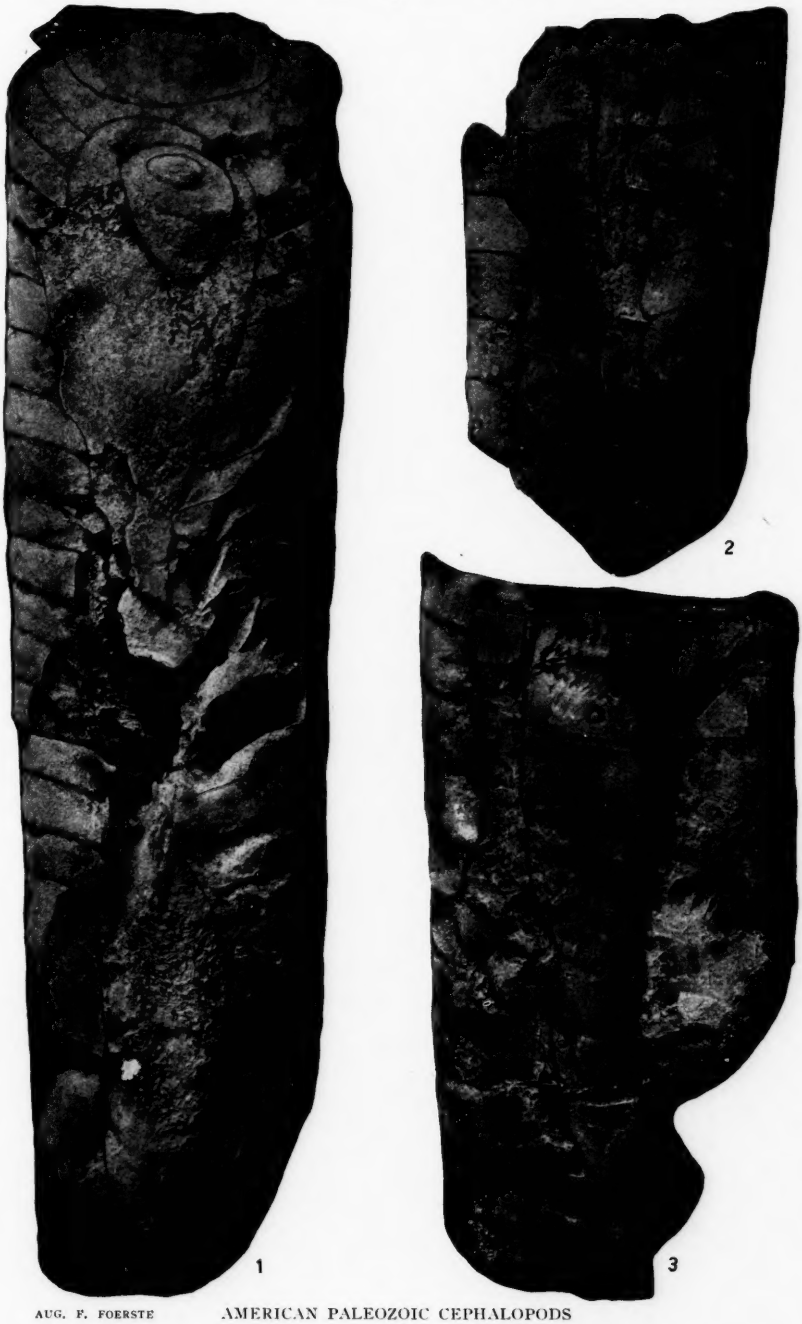

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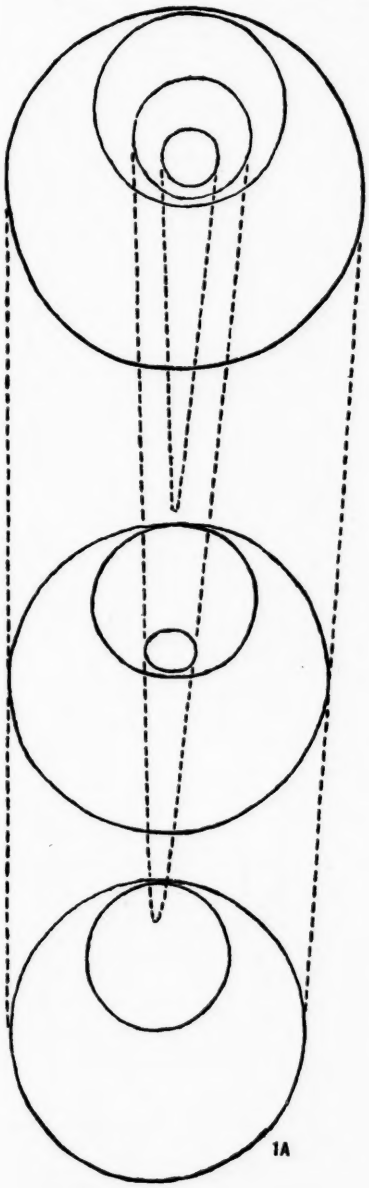
PLATE XXII

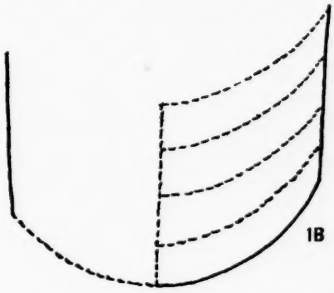
Fig. 1. *Endoceras proteiforme* Hall. A, three transverse sections of the type specimen at intervals corresponding to the distances between the centers of the sections; showing the rate of increase of the conch, siphuncle, and endocones. B, diagrammatic ventro-dorsal vertical section of the same specimen. See also fig. 1 on pl. XXI.

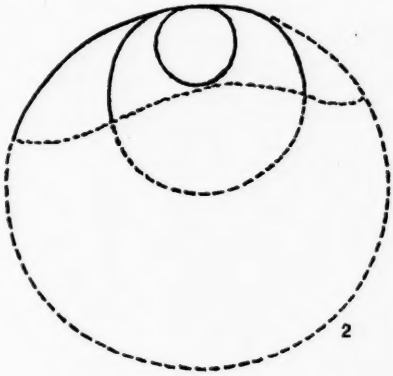
Fig. 2. *Endoceras proteiforme* Hall. Transverse section of same specimen as fig. 2 on pl. XXI, with missing parts indicated by broken lines. See also fig. 2 on pl. XXIII.

Fig. 3. *Endoceras proteiforme* Hall. Transverse section of same specimen as fig. 2 on pl. XXV, with missing parts indicated by broken lines. See also fig. 3 on pl. XXIII.

All specimens figured on this plate are from Middleville New York, in the Trenton limestone.


1A


1B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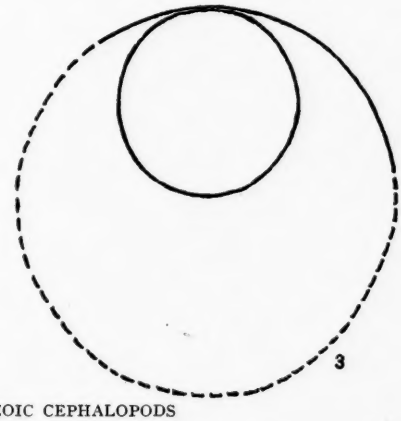
3

PLATE XXIII

Fig. 1. *Endoceras proteiforme* Hall. A, vertical section, showing the upper part of an endocone. B, cross-section showing siphuncle and endocone. Same specimen as fig. 3 on pl. XXI.

Fig. 2. *Endoceras proteiforme* Hall. Vertical section through the siphuncle, showing the apical part of an endocone. Same specimen as fig. 2 on pl. XXI, and fig. 2 on pl. XXII.

Fig. 3. *Endoceras proteiforme* Hall. Vertical section of the endocone in fig. 1e of pl. 49 of the Pal. of New York, vol. 1, 1847, to show its rate of taper and its form before it was distorted. See also fig. 2, on pl. XXV, and fig. 3 on pl. XXII.

All specimens figured on this plate are from Middleville, New York, in the Trenton limestone.

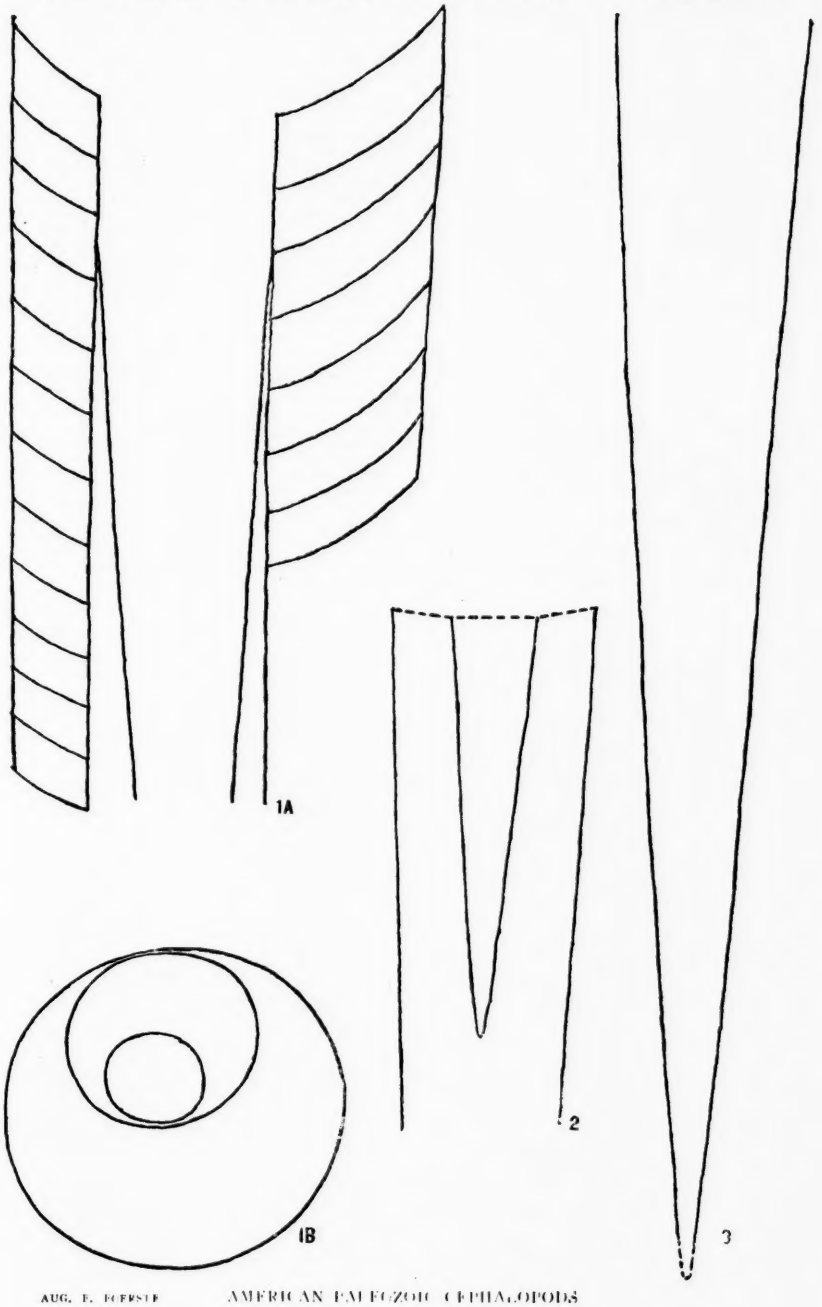
1A
1B
2
3

PLATE XXIV

Figs. 1-5. *Cameroceras trentonense* Hall. 1, 2A, lateral views showing siphuncle. 2B, ventral view of 2A. 3, cast of interior of siphuncle and endocone; compare with 5. 4, lateral view, exposing one segment of the siphuncle. 5, endocone, thickened interiorly by a calcareous deposit, lighter in color, contrasting with the darker color of the matrix filling the interior of the endocone. 1, 2, from Middleville, New York; No. 815 in American Museum of Natural History; originals of Pal. New York, vol. 1, 1847, pl. 56, figs. 4 a, b, c. 3, 4, from Multona brook, 2 miles northeast of Middleville, New York; No. 59449, in the U. S. National Museum. 5, from Poland, in Herkimer, New York; No. 59450, in the U. S. National Museum. All specimens from the Trenton limestone.

Figs. 6 A-E. *Cameroceras calumettense* Foerste. A lateral view; B, view of same specimen, facing the interior of the conch. C, ventral side of another specimen. D, E, opposite sides of an endocone split so as to show the thicknened inner walls of the endocone, but omitting the deposit of matrix which filled its interior. At the base of the specimen, the axial part of the calcareous deposit is occupied by a thin transverse band, scarcely 1 mm. in width. From Little Calumet creek, 6 miles south of Louisiana, Missouri. In the U. S. National Museum.

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PLATE XXV

Figs. 1 A, B. *Diestoceras indianense* (Miller and Faber). A, ventral view. B, lateral view of same specimen. From Little Four Mile creek, near Oxford, Ohio; in the lower part of the Whitewater member of the Richmond. Collected by Prof. W. H. Shideler of Miami University.

Fig. 2. *Endoceras proteiforme* Hall. Lateral view, with ventral side on left. See also Plate XXII, Fig. 3; Plate XXIII, Fig. 3. From Middleville, New York. Same specimen as Fig. 1e on Pl. 49, of the Pal. New York, vol. 1, 1847. In the Trenton limestone.

Fig. 3. *Orthoceras breynii* Martin. Ventral side. Figure copied from Petrefacta Derbiensis, 1809, pl. 39, fig. 4. Stated to be frequent in black marble at Ashford. A Carboniferous species.

Fig. 4. *Orthoceras annularis* Fleming. Lateral view, inverted from original. Copied from Fleming, Ann. Phil., pl. 31, Fig. 8. Carboniferous.

Fig. 5. *Orthoceras annulare* Phillips. Lateral view. Copied from Phillips, Geology of Yorkshire, 1836, pl. 21, fig. 9. Carboniferous.

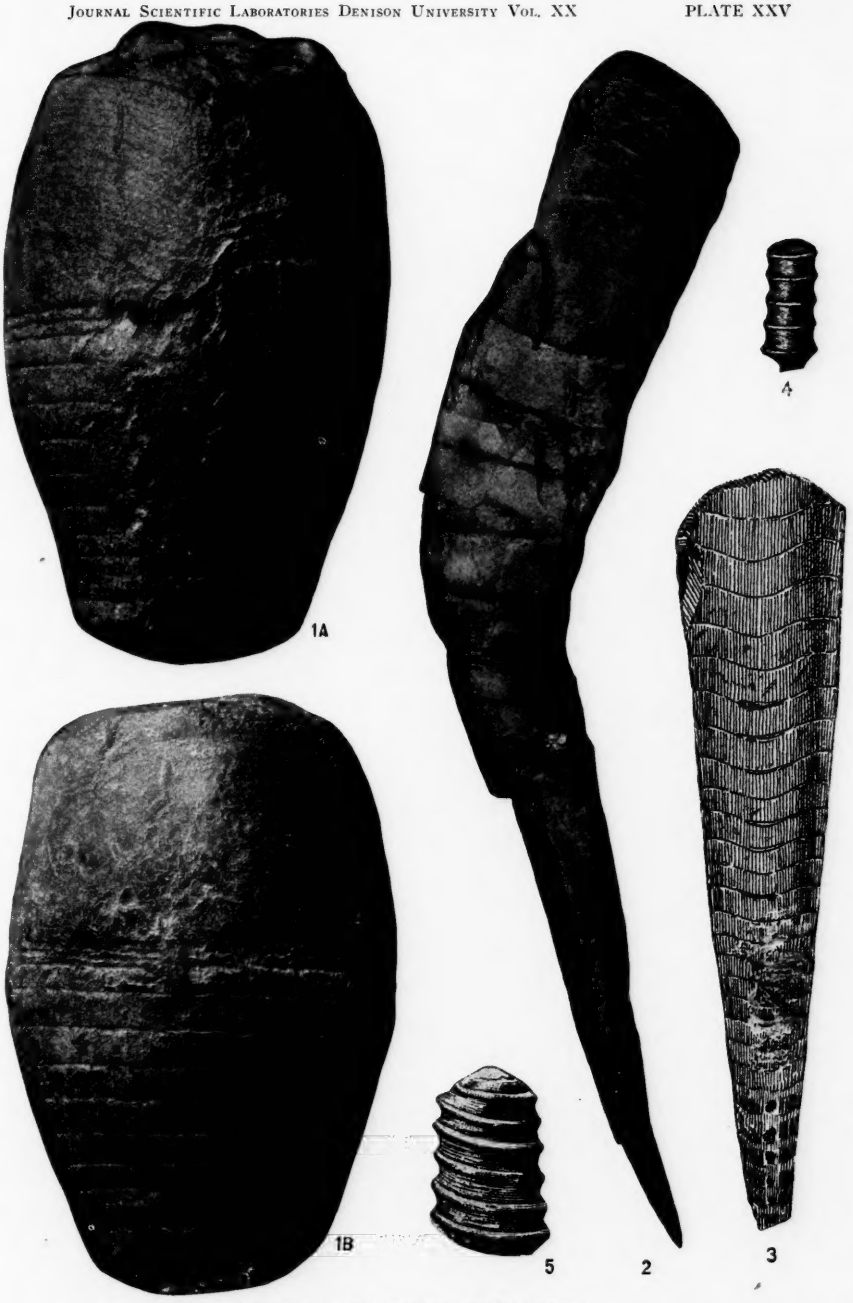

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PLATE XXVI

Figs. 1 A, B. *Diestoceras indianense* (Miller and Faber). A, lateral view. B, ventral view. From Little Four Mile creek, near Oxford, Ohio. Collected by Prof. W. H. Shideler, of Miami University.

Figs. 2 A, B. *Diestoceras indianense* (Miller and Faber). A, vertical dorso-ventral section showing poorly preserved siphuncle. B, same specimen. From Little Four Mile creek, near Oxford, Ohio. Collected recently by C. L. Faber, from the basal part of the Whitewater member of the Richmond formation.

1A
1B
2A
2B

PLATE XXVII

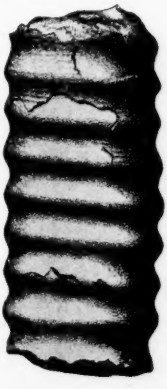
Figs. 1 A, B. *Diestoceras shideleri* Foerste. A, lateral view with ventral side on right. B, ventral view, with siphuncle at base. From the basal part of the Whitewater member of the Richmond. Collected by Prof. W. H. Shideler, of Miami University.

Fig. 2. *Diestoceras* cf. *indianense* (Miller and Faber). View showing the surface striae. From the Saluda member of the Richmond. Collected by Prof. W. H. Shideler.

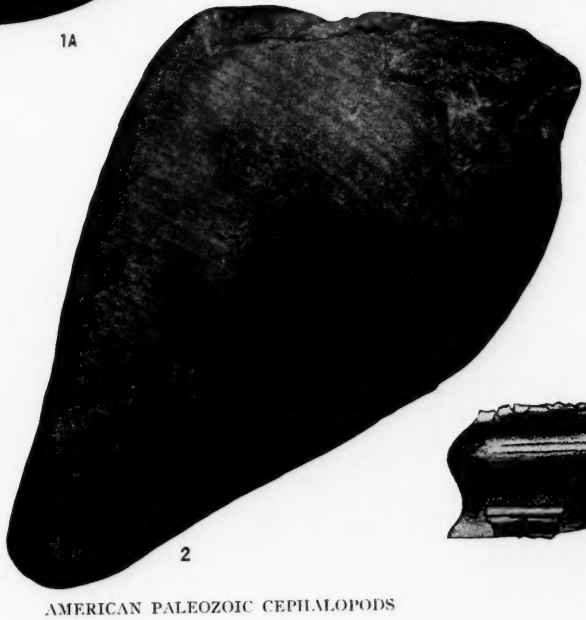
Figs. 3 A, B. *Perigrammoceras laevigatum* (McCoy). A, partly exfoliated conch, with surface of shell showing transverse striae. B, part of specimen enlarged, showing surface striae. Copied from Foord, Carb. Ceph. Ireland, 1897, pl. 5, figs. 1d, 1e. Of Carboniferous age.

1A

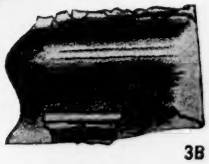
1B



3A



2



3B

PLATE XXVIII

Figs. 1 A, B. *Diestoceras eos* (Hall and Whitfield). Opposite sides of the same specimen. Ventral side assumed to be near left side of A, and right side of B. From vicinity of Dayton, Ohio, assumed to be from basal part of Whitewater member of Richmond. Type, numbered 3082, in the Geological Museum of Ohio State University. Same specimen as that figured in Ohio Pal., 2, 1875, pl. 3, fig. 5.

Figs. 2 A, B. *Loxoceras distans* McCoy. A, lateral view with ventral side on right. B, cross-section, with lateral diameter larger. Copied from McCoy, Carb. Foss. Ireland, 1844, pl. 4, fig. 1. From the Carboniferous.

Fig. 3. *Lituites* sp. Vertical section through a fragment, from a large series of specimens from Esthonia, in the U. S. National Museum.

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PLATE XXIX

Figs. 1 A, B, C. *Amphicyrtoceras orcas* (Hall). A, ventral view. B, lateral view showing the septa. C, two cross-sections, one taken at the base of the living chamber, the other 5 camerae lower. From Waukesha, Wisconsin; in the Racine member of the Niagaran. Type, numbered 2112, in the American Museum of Natural History. Same specimen as in 20th Rep. New York State Mus. Nat. Hist., 1868, pl. 17, figs. 1, 2.

Figs. 2 A, B, C. *Amphicyrtoceras tantalum* Foerste. A, ventral view. B, lateral view. C, two cross-sections, one at base of living chamber, the other at base of specimen. From railroad quarry in northeastern edge of Hillsboro, Ohio; from the Cedarville member of the Niagaran.

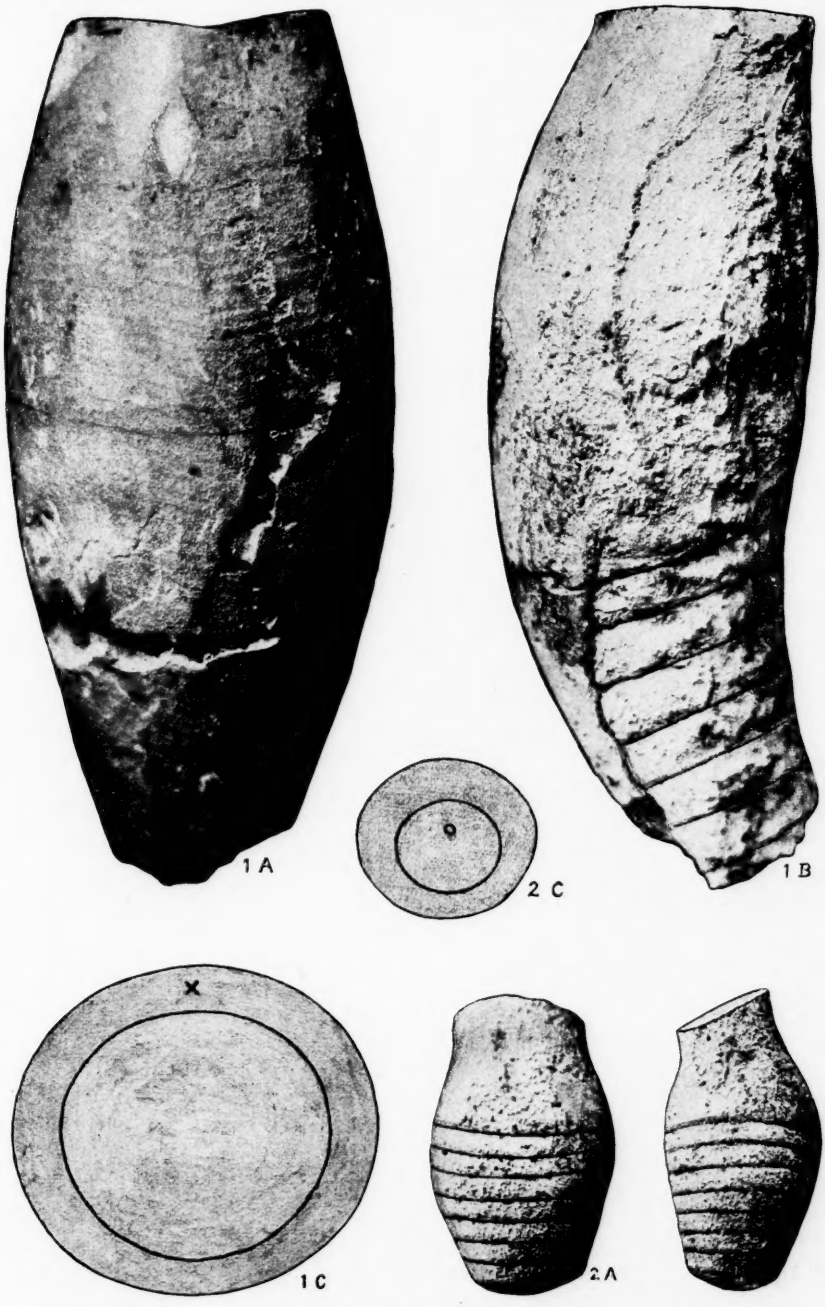

1A
2C
1B
1C
2A

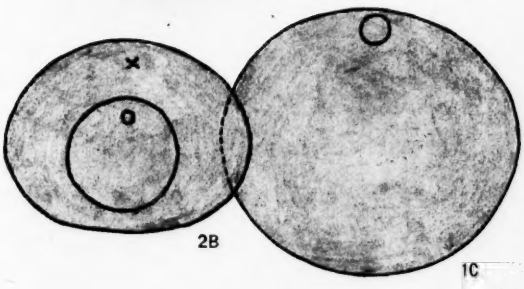
PLATE XXX

Figs. 1 A, B, C, D. *Amphicyrtoceras laterale* (Hall). A, dorsal view. B, lateral view. C, cross-section at base of the living chamber. D, vertical dorso-ventral section, exposing the siphuncle, taken at top of phragmacone. From Racine member of Niagaran at some Wisconsin locality. No. 634, in the Public Museum of Wilwaukee, Wisconsin.

Figs. 2 A, B. *Amphicyrtoceras laterale* (Hall). A, ventral view. B, two cross-sections, one at base of living chamber, the other at base of specimen. From Racine, Wisconsin, in the Racine member of the Niagaran. Type, numbered 2119, in the American Museum of Natural History. Same specimen as that figured in 20th Rep. New York State Museum Nat. Hist., 1868, pl. 18, figs. 4, 5, 6.

1A

1B



2B

1C

2A

1D

PLATE XXXI

Fig. 1. *Charactoceras baeri* (Meek and Worthen). Lateral view. See also plate XXXII, figs. 1A, B. From vicinity of Oxford, Ohio, in the basal part of the Whitewater member of the Richmond. Collected by Prof. W. H. Shideler, of Miami University.

Figs. 2 A, B, C, D. *Tripteroceras hastatum* (Billings). A, ventral side, exposing the siphuncle. B, view of upper end, showing passage of siphuncle through septum. C, diagrammatic lateral view, showing the lateral saddles. D, diagram showing relative depth of dorsal and ventral lobes of the sutures. From Pauquette Rapids, in Ottawa River, Canada, in the Leray member of the Black River. Selected type, numbered 1281, in the Victoria Memorial Museum at Ottawa, Canada.

Figs. 3 A, B, C, D. *Tripteroceras pauquettense* Foerste. A, lateral view. B, ventral view. C, diagram showing relative depth of dorsal and ventral lobes of sutures. D, cross-section at top of specimen, showing passage of siphuncle through septum. Part of the type series of *Tripteroceras hastatum* (Billings), numbered 1281 d, in the Victoria Memorial Museum, at Ottawa, Canada. Selected here as type of new species.

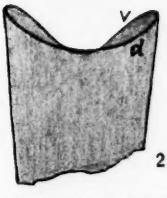
2A

2B

3D

3A

2C



2D

3C

3B

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PLATE XXXII

Figs. 1 A, B. *Charactoceras baeri* (Meek and Worthen). A, ventral view including top of phragmacone and base of living chamber. B, ventral view of living chamber, showing hyponomic sinus. Same specimen as Plate XXXI, Fig. 1.

1B

1A

PLATE XXXIII

Figs. 1 A, B. *Charactoceras baeri* (Meek and Worthen). A, lateral view. B, ventral view, including upper part of phragmacone and basal part of living chamber. From vicinity of Oxford, Ohio, in the basal part of the Whitewater member of the Richmond. Collected by Prof. W. H. Shideler, of Miami University.

1B

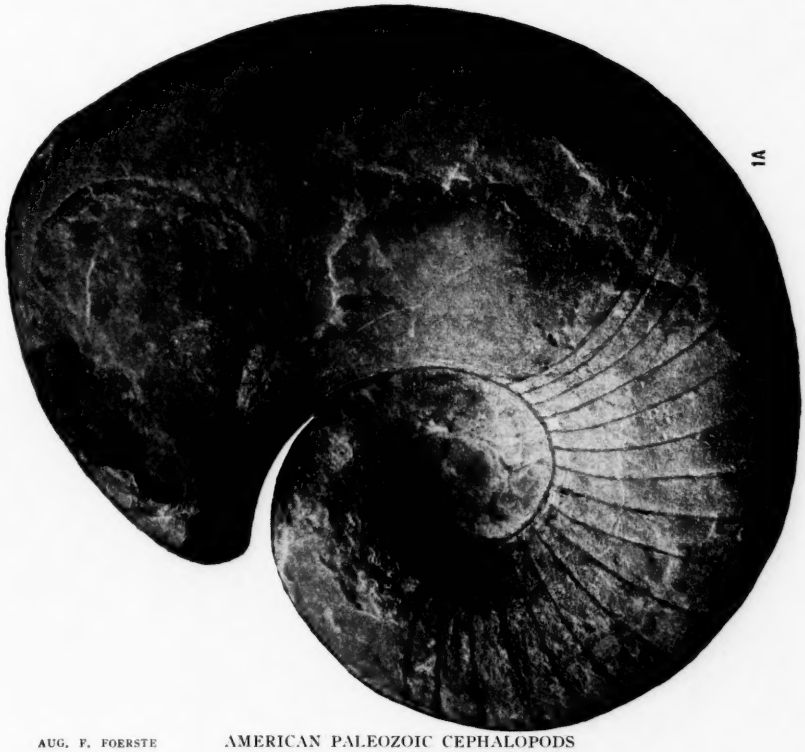
1A

PLATE XXXIV

Fig. 1 A, B. *Charactoceras baeri* (Meek and Worthen). A, ventral view of an incomplete specimen, showing the surface striae. B, lateral view of the same specimen. From the vicinity of Oxford, Ohio, in the basal part of the Whitewater member of the Richmond. Collected by Prof. W. H. Shideler, of Miami University.

Fig. 2. *Charactoceras baeri* (Meek and Worthen). Dorso-ventral section, exposing the siphuncle. From Flat Fork, 4 miles northeast of Oregonia, Ohio, in the basal part of the Whitewater member of the Richmond. Collected by Prof. J. E. Carman, of Ohio State University.

2
1B
1A

PLATE XXXV

Figs. 1 A, B. *Elrodoceras indianense* (Miller). A, B, lateral views of opposite sides of the same specimen, A showing the sutures of the septa, and B showing the surface striae. From some Indiana locality, in the upper part of the Laurel member of the Niagaran. Specimen No. 2133 in the Museum of Comparative Zoology, at Harvard University. Second type of *Rhynchorthoceras dubium* Hyatt. See also Plate XXXVI, Figs. 1A, B.

Figs. 2 A, B, C. *Billingsites* (?) *williamsportense* Foerste. A, lateral view. B, more convex side, assumed to be ventral. C, less convex side, assumed to be dorsal. From Williamsport, Tennessee. Specimen No. 48395, in the U. S. National Museum.

1A
2A
1B
2B
2C

PLATE XXXVI

Figs. 1 A, B. *Elrodoceras indianense* (Miller). A, ventral view showing the surface striae. B, opposite side of same specimen, showing the camerae, and the top of the siphuncle. From some locality in Indiana, in the upper part of the Laurel member of the Niagaran. Chief type of *Rhynchoroceras dubium* Hyatt, numbered No. 2132, in the Museum of Comparative Zoology, at Harvard University.

Figs. 2 A, B. *Beloitoceras lycum* (Hall). A, lateral view, cast of interior. B, ventral view. From Beloit, Wisconsin, in the Beloit member of the Black River. No. 999, in the American Museum of Natural History. Same specimen as Amer. Mus. Nat. Hist., Bull. 1, pt. 2, 1895, pl. 9, figs. 13, 14. See also Plate XLI, figs. 6 A, B, in this Journal.

Figs. 3 A, B. *Beloitoceras plebeium* (Hall). A, lateral view, cast of interior. B, ventral view. From Beloit, Wisconsin, in the Beloit member of the Black River. Specimen numbered 996, in the American Museum of Natural History. Same specimen as that figured by Whitfield, in Bull. Amer. Mus. Nat. Hist., 1, pt. 2, 1895, pl. 9, figs. 18, 19.

Figs. 4 A, B. *Beloitoceras plebeium* (Hall). A, lateral view, cast of interior. B, ventral view. From Beloit, Wisconsin, in the Beloit member of the Black River. Specimen numbered 996, in the American Museum of Natural History. Same specimen as that figured by Whitfield, in Bull. Amer. Mus. Nat. Hist. 1, pt. 2, 1895, pl. 9, figs. 15, 16. See also Plate XLI, figs. 5 A, B.

Figs. 5 A, B. *Beloitoceras pandion* (Hall). A, lateral view, cast of interior. B, ventral view. From Beloit, Wisconsin, in the Beloit member of the Black River. Specimen numbered 998, in the American Museum of Natural History. Same specimen as that figured by Whitfield, Bull. Amer. Mus. Nat. Hist., 1, No. 2, pl. 9, figs. 21, 22. See also Plate XLI, figs. 4A, B, C.

The lines over figures 3A and 4A indicate the probable outline of the aperture on lateral view.

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PLATE XXXVII

Fig. 1. *Monocyrtoceras lentidilatatum* Foerste. Lateral view, exposing one segment of the siphuncle at the base. See also Plates XXXVIII, fig. 1; XXXIX, fig. 1; XL, figs. 1 A, B; and XLI, figs. 3 A, B. From Greenfield, Wisconsin, in the Racine member of the Niagaran. Specimen No. 2315 in the Museum of Comparative Zoology, at Harvard University.

Fig. 2. *Elrodoceras indianense* (Miller). Ventral side, retaining the transverse surface striae. From Hartsville, Indiana, in the Laurel member of the Niagaran. Same specimen as that figured by Miller, in 17th Ann. Rep. Dep. Geol. Nat. Res. Indiana, 1892, pl. 18, fig. 2.

Fig. 3. *Elrodoceras* cf. *indianense* (Miller). Natural section, exposing the siphuncle. From Lemont, Illinois, in the Niagaran. Specimen No. 22917, in the Museum of Comparative Zoology, at Harvard University. See also Plate XXXVIII, fig. 2.

2

3

PLATE XXXVIII

Fig. 1. *Monocyrtoceras lentidilatatum* Foerste. Ventral view, exposing one segment of the siphuncle at the base. Same specimen as Plate XXXVII, fig. 1.

Fig. 2. *Elrodoceras indianense* (Miller). Lateral view, with ventral side on right; exposing 4 segments of the siphuncle. Same specimen as Plate XXXVII, fig. 2.

Fig. 3. *Elrodoceras* cf. *indianense* (Miller). Lateral view of part of cast of interior of siphuncle, showing relative size of passage of siphuncle through septum at top of specimen. From Joliet, Illinois, in the Niagaran. No. 22916, in Walker Museum, at University of Chicago.

Fig. 4. *Actinoceras* sp. Lateral view of cast of interior of siphuncle, showing nature of deposits here. From Joliet, Illinois, in the Niagaran. Also numbered 22916, in Walker Museum, but belonging to a different species from the preceding.

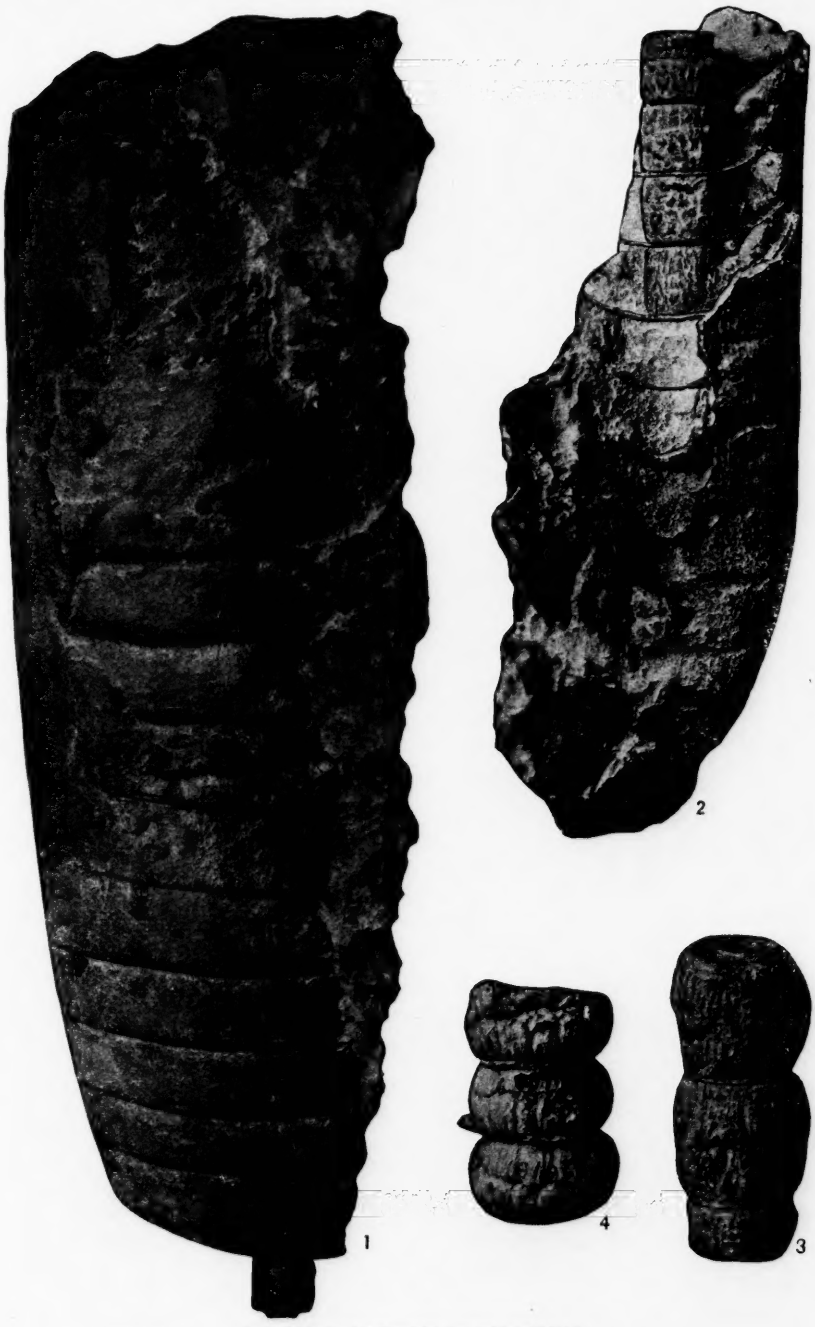

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PLATE XXXIX

Fig. 1. *Monocyrtoceras lentidilatatum* Foerste. Dorsal view, inverted in order to illuminate the side best preserved; with one segment of the siphuncle exposed. Same specimen as Plate XXXVII, fig. 1.

Fig. 2A, B. *Oncoceras constrictum* Hall. A, lateral view; B, ventral view of same specimen, showing surface striae. From Middleville, New York, in the Trenton limestone. Same specimen as 3rd Rep. New York State Museum, 1850, pl. 3, figs. 3 a, b.

Fig. 3. *Oncoceras constrictum* Hall. Lateral view, exposing base of living chamber. From Middleville, New York, in the Trenton limestone. Same specimen as Pal. New York, 1, 1847, pl. 41, figs. 6 a, b, c.

Fig. 4. *Oncoceras constrictum* Hall. View of septum at base of another specimen, showing passage of siphuncle through septum. From Middleville, New York, in Trenton limestone. Same specimen as Pal. New York, 1, 1847, pl. 41, figs. 7 a, b, c.

Figs. 5 A, B, C. *Maelonoceras billingsi* Foerste. A, lateral view, with ventral side on left. B, view of aperture. C, ventral view. From LaCloche Island, in northern Lake Huron, in the Black River. Specimen No. 1294, in Victoria Memorial Museum. One of two specimens described and figured by Billings under *Phragmoceras praematurum.*

Figs. 6 A, B, C. *Maelonoceras praematurum* (Billings). A, dorsal view. B, lateral view with ventral side on left. C, lateral view with ventral side on right, surface showing transverse striae. From LaCloche Island, in northern Lake Huron. One of two specimens described and figured under *Phragmoceras praematurum.* See also Plate XLI, fig. 7.

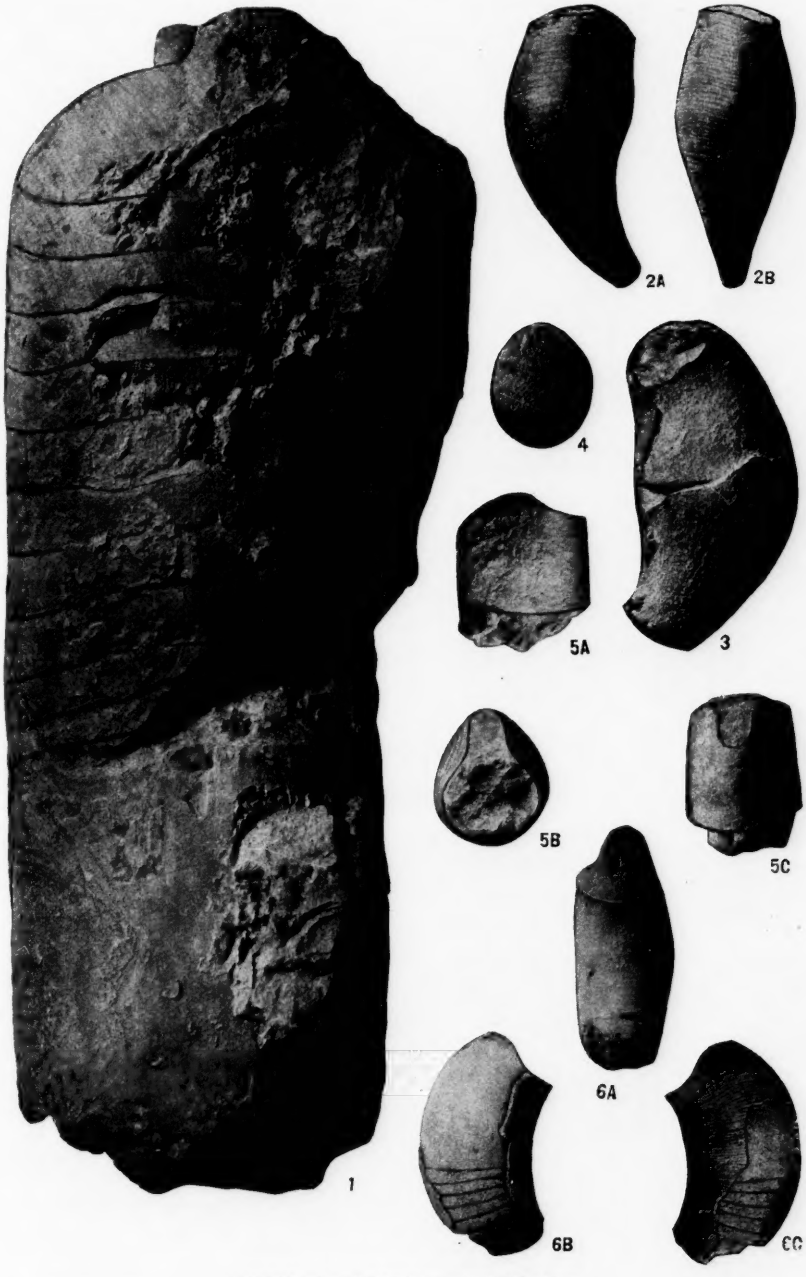

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PLATE XL

Figs. 1A, B. *Monocyrtoceras* cf. *lentidilatatum* Foerste. A, lateral view; B, ventral view. Neither presents the outline of the aperture, although the full height of the living chamber appears to be retained by the specimen. From Wauwatosa, Wisconsin, in the Racine member of the Niagaran. Specimen No. 2312, in Museum of Comparative Zoology, at Harvard University.

Fig. 2. *Poterioceras fusiforme* (Sowerby). Lateral view. Copied from Foord, Carb. Ceph. Ireland, 1897, pl. 15, fig. 2b. From the Carboniferous.

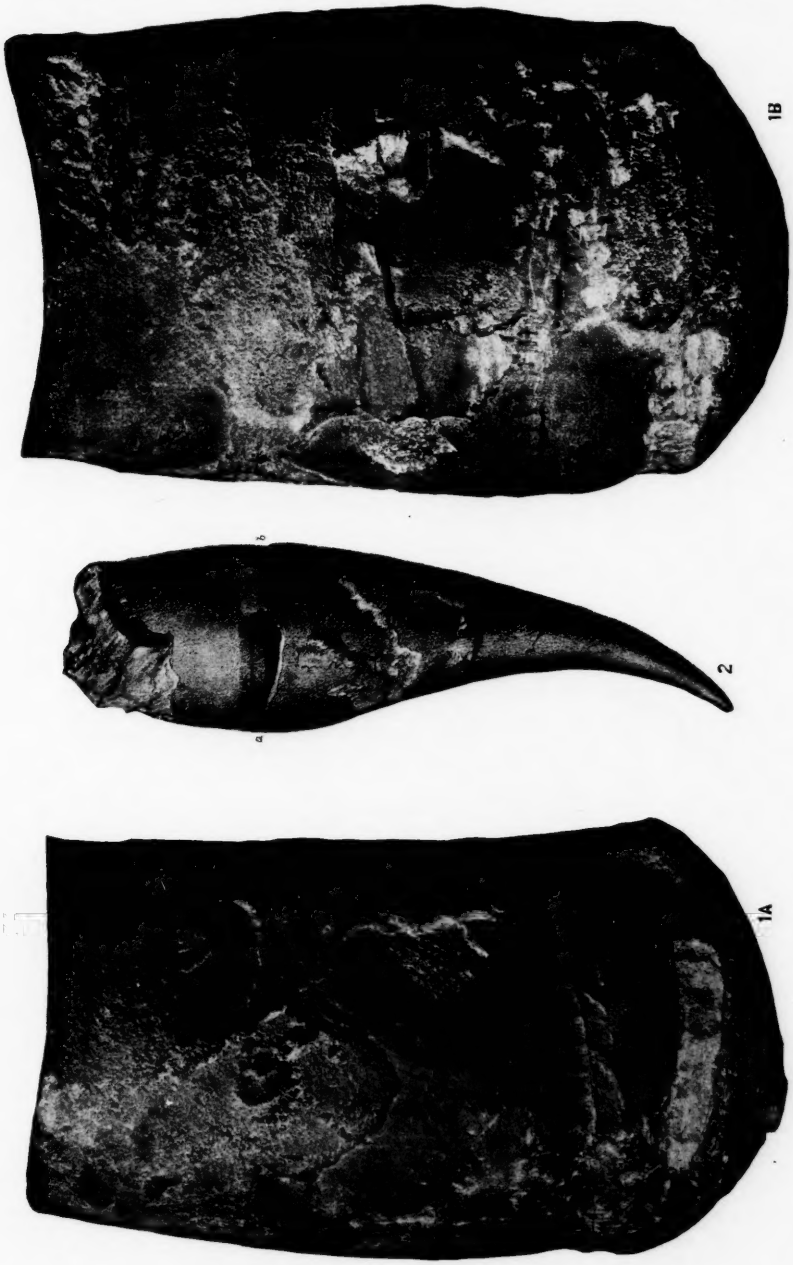

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PLATE XLI

Figs. 1 A, B. *Poterioceras fusiforme* (Sowerby). Diagram, showing outline of conch, course of sutures along upper part of phragmacone, and vertical section through lower part of specimen. B, siphuncle of same specimen, enlarged. From Kildare, Ireland, in the Carboniferous. Specimen No. 2177, in the Museum of Comparative Zoology, at Harvard University.

Fig. 2. *Charactoceras baeri* (Meek and Worthen). Cross-section at three points across the same phragmacone, to show the change in form with age. Same specimen as Plate XXXIV, fig. 2.

Fig. 3 A, B. *Monocyrtoceras lentidilatatum* Foerste. A, cross-section showing location of siphuncle. B, dorso-ventral section, showing general outline of siphuncle. Same specimen as Plate XXXVII, fig. 1.

Fig. 4 A, B, C. *Beloitoceras pandion* (Hall). A, outline of aperture. B, cross-section of conch. C, dorso-ventral section through siphuncle, enlarged. Same specimen as Plate XXXVI, figs. 5 A, B, C.

Figs. 5 A, B. *Beloitoceras plebeium* (Hall). A, outline of aperture. B, cross-section of conch, at largest diameter. Same specimen as Plate XXXVI, figs. 4 A, B, C.

Figs. 6 A, B. *Beloitoceras lycum* (Hall). A, cross-section of conch at largest diameter. B, dorso-ventral section through siphuncle. Same specimen as Plate XXXVI, figs. 2 A, B.

Fig. 7. *Maelonoceras praematurum* (Billings). Vertical dorso-ventral section, showing fusiform segments of siphuncle. Same specimen as pl. XXXIX, figs. 6 A, B. C.

Fig. 8. *Clarkoceras mercurius* (Billings). Vertical dorso-ventral section, with siphuncle on left side, showing concave vertical outline of segments of the siphuncle; enlarged. Diagrammatic drawing prepared from the type specimen No. 826, in the Victoria Memorial Museum, at Ottawa, Canada. Originally described under *Cyrtocerina.*

Fig. 9. *Cyrtocerina typica* Billings. Vertical dorso-ventral section, with siphuncle on left side, showing convex vertical outline of segments of the siphuncle; enlarged. Diagrammatic drawing prepared from the type specimen, No. 1301, found at Pauquette Rapids, on Allumette Island, in the Black River formation. In Victoria Memorial Museum, at Ottawa, Canada.

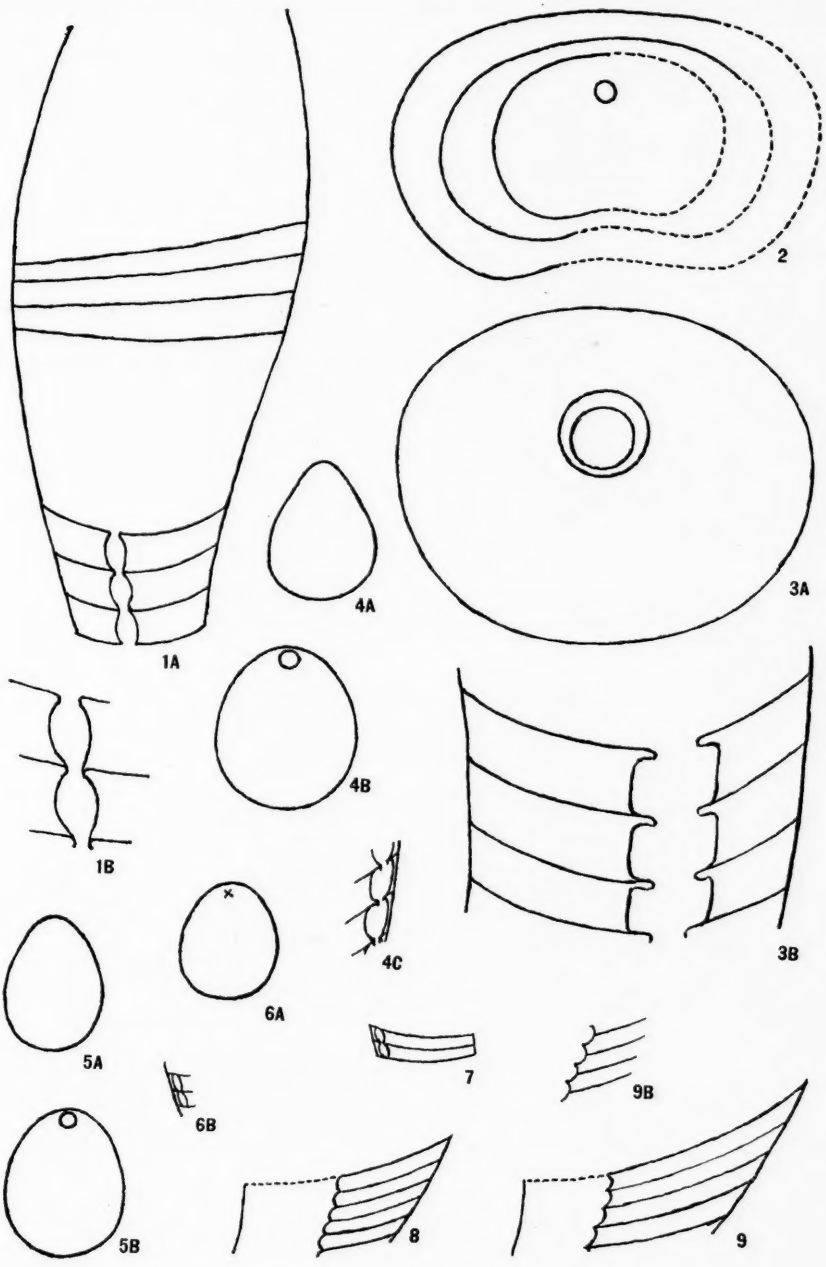
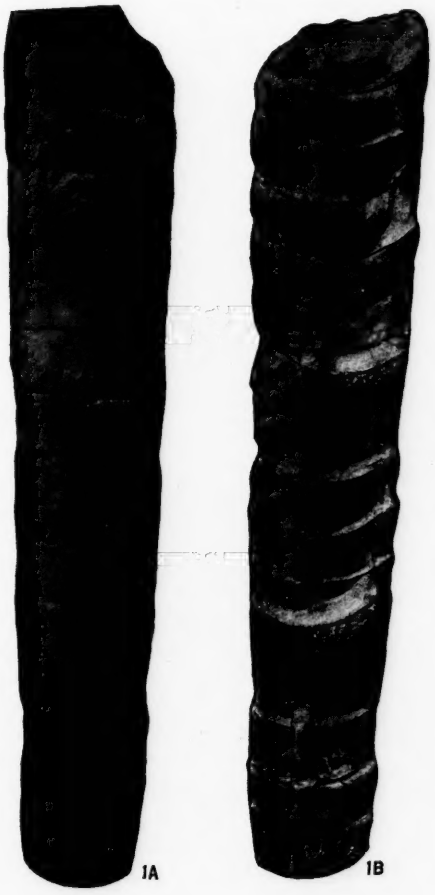

1A
2
3A
4A
1B
4B
4C
3B
6A
5A
7
9B
6B
5B
8
9

PLATE XLII

Figs. 1 A, B. *Orthoceras clarksvillense* Foerste. A, cast of interior of conch. B, natural vertical section of same specimen, showing the cylindrical segments of the siphuncle. Specimen No. 48255, in the U. S. National Museum. From the Waynesville member of the Richmond formation at Clarksville, Ohio.


1A
1B

A REPORT ON THE THEORY OF RELATIVITY. (EINSTEIN THEORY)

PAUL BIEFELD

During the past twenty-five to thirty years phenomenal work has been done in the physical sciences. We need only recall X-rays, followed by radioactivity, then electrons and wireless. The experimental work along these lines has, however, also brought into question some of the fundamental principles of the science itself; leading to the abandonment, notably, of the following three: the unchangeableness of the atom, the independence of space and time, and the continuity of dynamical action. The letting go of the first led to the electron theory, of the second to the theory of relativity, and of the third to the quantum theory. The corner stones of the structure have, however, been in no wise affected. The principle of the conservation of energy and that of the conservation of mass, although the latter has been merged into the first by the restricted theory of relativity; the laws of thermodynamics; the principle of least action; all of these have been all the more firmly established. They have stood the fire of searching experiment of modern physics.

The Restricted Principle of Relativity

It is necessary at the outset to consider the concepts of space and time, in particular the relation of these concepts to experience. In this connection the terms "absolute space" and "absolute time" have no meaning. The physicist thinks of space only in connection with the occurrence of events. In fact it is not even the point in space 'where' something is, nor the instant of time 'when' something happens, but the event itself, that is to him the only physical reality.

We shall consider the distance or space interval between two points referred to a body of reference or frame of reference expressed in Cartesian coordinatee. Calling x_1, x_2, x_3 the coordinates, the interval becomes:

$$s^2 = \Delta x_1^2 + \Delta x_2^2 + \Delta x_3^2 \qquad (1)$$

in which the Δx's are the projections of the interval on the axes,

the axes being thought of as rigid rods and the unit length a short rigid bar.

Time is expressed by means of a body, or system, called a clock that counts off events, the intervals between them being considered of equal length.

Time and space as above defined serve only to represent to the physicist the complex of experiences relating to the events observed by him.

To give a physical significance to the concept of time and to establish definite relations between different points in space a physical process of some kind must be used. As the propagation of electromagnetic radiations or light in vacuum is the one that has been most accurately investigated and determined, this is chosen for the purpose; not for the reason, however, as has been brought forward by some of the objectors to the theory, that this particular process is essential to the theory; any other equally well determined process would serve as well.

There are two postulates on which the theory rests: the principle of relativity and the constancy of the velocity of light; stated definitely as follows:

1. The laws according to which the physical conditions of systems change are independent of the fact to which of two frames of reference, having relative uniform rectilinear motions, these changes of conditions are referred. (Relativity of uniform motions.)

2. Light has a definite and constant velocity "c" in a frame of reference at rest, independent of the fact whether the source of light is in motion or at rest.

Let a clock be placed at a point A where an observer may "time" an event in its immediate vicinity and a second similar clock placed at a point B where a second observer may "time" an event in a similar manner; this does not lead, however, without further consideration to the fact that the times of the events at A and B may be directly compared. For we have up to this time only defined a 'time at A' and a 'time at B' but not a 'common time.' This common time will now be defined by means of the second postulate; stating, that it takes the same time for light to travel from A to B, as it does to go from B to A.

We therefore send a light signal from A to B where it is reflected to A. Let t_A be the time at A or the 'A-time' and t_B be the

time at B or 'B-time' and t'_A the time of arrival of the reflected ray at A. The clocks then run synchronously if $t_B - t_A = t'_A - t_B$ This equation defines 'time' and 'symultaneity of time'. The velocity of light is then also defined by:

$$c = \frac{2AB}{t'_A - t_A} \tag{2}$$

We may now assume the uniform velocity of light in all directions, there being no reason for assuming the direction A–B as unique.

Assuming now A as the source of light and at the same time the origin of a frame of reference K at rest. If r is the distance of the point B from A; after the time $\triangle t$ the wave front will be the surface of sphere passing through B, for according to the second postulate the equation holds:

$$r = c.\triangle t$$

If we express the difference of coordinates by $\triangle x_\nu$, ν from 1 to 3, and squaring we get

$$\Sigma(\triangle x_\nu)^2 - c^2\triangle t^2 = 0 \tag{3}$$

This equation evidently formulates the principle of the velocity of light relative to K which must be independent of the motion of the source A.

We now take another frame of reference K′ in uniform rectilinear motion relative to K. K and K′ are then inertial systems.

With respect to K′ we have the equation:

$$\Sigma(\triangle x'_\nu)^2 - c^2\triangle t^2 = 0 \tag{3a}$$

Equations (3) and (3a) must be mutually consistent with each other with respect to a definite transformation, transforming K′ into K. Again an interval has a physical meaning only if it is independent of the choice of coordinates which is true evidently also of the spherical surfaces represented by (3) and (3a).

We will now develop the Lorentz transformation in an elementary way.

Let the x_1 coordinate axis be parallel to the x'_1 axis and $x_2 = x'_2$ also $x_3 = x'_3$ of K and K′ respectively. Furthermore we must have:

$$x_1^2 - c^2t = x'^2_1 - ct'^2 \tag{4}$$

and

$$x'_1 = k(x_1 - vt); \quad x_1 = k'(x'_1 + vt') \tag{5}$$

in which k and k′ are constants depending only on c, the velocity of light; and v, the relative velocity of K′ with respect to K. We calculate now from the second equation of (5) with the aid of the first of (5):

$$t'=k\left[t-\frac{x_1}{v}\left(1-\frac{1}{kk'}\right)\right] \qquad (6)$$

and put the value of x'_1 and t′ from (5) and (6) into equation (4) A comparison of the coeficients of x^2_1, t^2 and x_1t leads to:

$$k=k'=\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

Substituting k and k′ in (5) and (6) we get:

$$x'_1=\frac{x_1-vt}{\sqrt{1-\frac{v^2}{c^2}}},\quad t'=\frac{t-\frac{v}{c^2}x_1}{\sqrt{1-\frac{v^2}{c^2}}},\quad \text{and } x'_2=x_2,\ x'_3=x_3 \qquad (7)$$

Solving for x_1, t, x_2 and x_3 we get:

$$x_1=\frac{x'_1+vt'}{\sqrt{1-\frac{v^2}{c^2}}},\quad t=\frac{t'+\frac{v}{c^2}x'_1}{\sqrt{1-\frac{v^2}{c^2}}}\quad \text{and}\quad x_2=x'_2,\ x_3=x'_3 \qquad (8)$$

These equations were for the first time developed by H. A. Lorentz hence the name "Lorentz transformation."

Let us place a number of synchronous clocks in the system K. If their rates are zero they will remain synchronous. Some of these clocks are now transferred to the system K′ having its axes parallel to those of K and moving relative to K with a uniform rate parallel to the X_1 axis. The clocks in K′ as seen by an observer at rest in K, will depart from synchronism relative to the clocks in K, losing time or going slower. Rods of definite length as measured in K if placed in K′ after they have been given the same motion as the system K′, and placed in the X'_1 axis will seem contracted as viewed by the same observer at rest in K. If the velocity of K′ with reference to K is known, both the change of rate of the clocks and the contraction of the rods may be numerically accounted for by means of the Lorentz transformation given above. It is of course evident that these changes will be extremely small on account of the second order effect: $\sqrt{\frac{v^2}{c^2}}$ occurring in the equation. If for instance v were as large as the orbital velocity of the earth, 18.5 miles per second, the value of the expression just given would be of the order $10.^{-8}$

It was also H. A. Lorentz who adopted the so-called contraction theory, first suggested by Fitzgerald, to satisfy his equations in connection with electron motion; assuming the contraction to be real the electrons taking on ellipsoidal form with their shorter axes in the direction of motion; hence the term "Lorentz contraction." In this theory there would, however, be involved some relation of this contraction to a corresponding physical change within the electron varying with the speed of the electron of which there is no trace. Einstein solved the enigma with one stroke by establishing the relativity of time and space leading to the same Lorentz equations but on a more rational basis.

Prof. Lorentz has the following to say in his Columbia lectures already referred to: " . . . he (Einstein) may certainly take credit for making us see in the negative result of experiments like those of Michelson, Rayleigh and Brace, not a fortuitous compensation of opposite effects, but the manifestation of a general and fundamental principle." And again: "It would be unjust to add that, besides the fascinating boldness of his starting point, Einstein's theory has another marked advantage over mine, whereas I have not been able to obtain for the equations referred to moving axes 'exactly' the same form as for those which apply to a stationary system, 'Einstein' has accomplished this by means of a system of new variables slightly different from those which I have introduced."

This was written in 1909 four years after the publication of Einstein's work on the Restricted theory, after the theory had been tested by Kaufman and Bucherer in connection with the extremely rapid moving β-rays establishing the forms for the longitudinal and transverse mass of the electron as:

$$m_l = \frac{m_o}{\sqrt{\left(1-\frac{v^2}{c^2}\right)^3}} \quad . \quad m_t = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}$$

distinguishing between the instantaneous motion in the x–direction as transverse, attaching these terms to the respective masses. At the present time the form has been simplified agreeing with that given by Lorentz in 1904, namely:

$$m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}$$

where m is the mass in motion, m_0 the mass at rest of the electron.

The principle is, however, not only true in connection with masses of electrons but also with respect to every ponderable mass as will be shown later.

Returning now to equations (3) and (3a) we will introduce the so-called 'light time,' $l=ct$; using this, these equations become:

$$\Sigma(\Delta x_\nu^2 - \Delta l^2)=0 \tag{9}$$

$$\Sigma(\Delta x_\nu'^2 - \Delta l'^2)=0 \tag{9a}$$

and the Lorentz transformation makes (9) a covariant equation which is satisfied with reference to every inertial system K', having a uniform rectilinear motion relative to K, if it is satisfied in the system K to which we have referred the two events: emission and reception of electromagnetic radiations or light.

At this point the genius of Mincowski steps in, introducing the time coordinate: $x_4=il$ $(i=\sqrt{-1})$
and equation (9) becomes:

$$\Sigma x_\nu^2 = 0 \quad \nu \text{ from 1 to 4} \tag{10}$$

and (9a)

$$\Sigma x_\nu'^2 = 0 \quad \nu \text{ from 1 to 4} \tag{10a}$$

Thus putting at once the time coordinate x_4 formally on the same footing as the space coordinates x_1, x_2, x_3. We say formally only because the relation of rationality must be considered. The space-time frame of reference of (10) and (10a) is Euclidean with one imaginary coordinate.

A point x_1, x_2, x_3, x_4 is called a 'world-point' and the line generated by the same a 'world-line,' and the continuum the 'world.' All events present themselves to the observer as intersections of world lines. Thus the event "twelve o'clock" as observed on a watch comes to us as the intersection of a world line through a point on the dial with a world line through a coincident point on the hands of the watch.

We shall now give another interesting consequence of the restricted theory.

According to this theory the conservation of mass, or more

strictly speaking of 'inertia mass,' has lost its meaning and is merged, as was indicated in the introduction, with the principle of the conservation of energy.

We have already treated of the change of mass of electrons by virtue of their motion and indicated there that the same was true of any mass. This comes about in the following way. The inertia mass changes if it takes up energy of radiation from without. The kinetic energy of a point mass in the pre-relativity mechanics is expressed by:

$$\frac{mv^2}{2}$$

according to relativity by:

$$\frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}$$

This expression becomes infinite as v approaches c, showing in the first place that it can not become equal to c, involving as this would an infinite amount of kinetic energy possessed by a point mass.

If the expression above is expanded in series we have:

$$mc^2+m\frac{v^2}{2}+\frac{3}{8}m\frac{v^4}{c^2}+\ldots.$$

The second term is the one standing for the kinetic energy in the old mechanics, the third term is very small if $\frac{v^2}{c^2}$ is small in comparison with unity, and the first term does not contain v; its meaning will come out in the subsequent discussion. If a moving body according to electrodynamics takes up the energy E in form of radiation, the increase of energy becomes:

$$\frac{E_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

and the energy of the body becomes:

$$\frac{(m+\frac{E_0}{c^2})c^2}{\sqrt{1-\frac{v^2}{c^2}}}$$

This body has therefor the same energy as a body of mass:

$$m+\frac{E_0}{c^2}$$

If we write the expression in the form:

$$\frac{mc^2+E_o}{\sqrt{1-\frac{v^2}{c^2}}}$$

we see that the expression mc^2 in the expansion is the energy which the point mass possessed before the body took up the energy E.

The General Theory of Relativity. (Theory of Gravitation).

The restricted theory is valid only in connection with bodies or frames of reference in uniform rectilinear motion relative to each other. There is no reason thinkable, however, why such systems should be preferred for other systems having any kind of motion; for we find nowhere in nature any such distinction indicated either in bodies or in the concept of motion. We are compelled then to look for the distinction as resting in the objective properties of the space-time continuum. We must attribute to this continuum a "field property" as we do in case of the electromagnetic field; and then find a way to extend the principle of relativity to frames of reference in non-uniform motion relative to each other.

We find a way of attack by the following consideration. In physics the ratio of the masses of two bodies is defined in two ways: first, as the inverse ratio of the accelerations imparted to them by the same force producing the motion; second as the direct ratio of the forces acting in the same gravitational field. In the first relation we call the mass "inertia mass" in the second "gravity or weight-mass." The ratio of these two masses have been found by Oetvoes so nearly equal to unity that the deviation is of the order of less than 5×10^{-8}. The examination included substances of crystaline structure and of radioactive nature. Inertia and gravity mass are then not only proportional but strictly equal. We have, however, no right in face of these results to maintain such an equality in thought unless it is reduced to an equality of nature of the two concepts. The statement of the equality of inertia-mass and gravity-mass is equivalent to the statement that the acceleration imparted to a body in a gravitational field is independent of the nature of the body; and it is the

extension of the principle of relativity that will establish the equality of the real nature of the two concepts.

A simple hypothetical experiment pointing to this extension will make the point made in the last paragraph clear. Let us consider a cubical box of sufficient size so that an observer provided with appliances for experiment finds room in the same. We further conceive of this box so far away from all bodies or masses so that it is not influenced by them in a gravitational way. The observer will experience great difficulty to stand upright. When lying on the floor the least impulse will send him to the ceiling. When he lets go of an object in his hand it will not fall to the floor. A body attached to a string fastened to the ceiling will not stretch the string unless pulled down by the observer which he would find hard to do on account of the instability of the bodies involved.

Let us now imagine a rope attached to the outside of the box and some being begin to pull at the same upward with a constant force, giving the box a uniform acceleration. The man inside the box will at once be able to stand upright in the box. Letting go of an object it will fall to the floor; looking at the body on the string he will see it hanging vertical with the string taut. In view of the observed facts the man has every reason to believe that he is in a "gravitational field."

Now let us further imagine an observer located at rest in space some distance to one side of the box. This observer would be of different opinion from the one in the box; he would say, the reason the string hangs taut and hangs in a vertical direction is due to the "inertia" of the upward accelerated box; and give a similar explanation with regard to the other phenomena occuring there.

The observer in the box then attributes to the body on the string "gravity mass"; the observer outside the box, "inertia mass." The two concepts are identical and, moreover, independent of the nature of the body.

Within the box the actual acceleration of bodies is strictly "equivalent" to a gravitational field.

We may now substitute for the box a frame of reference K′ limited, however, to the confines of the box; and for the region outside, where the second observer is located, a frame of reference K. K′ is uniformly accelerated with respect to K. Relative to K′ or as seen from K′, K is uniformly accelerated. K′, as seen

by the observer within, is at rest and a gravitational field present. This gravitational field may then be legitimately replaced, within the limits of the box, by the accelerated coordinate system K′. This principle of equivalence is evidently intimately related to the equality between the inertia-mass and gravitational-mass, and leads thus to the extension of the principle of relativity to frames of reference that are in non-uniform motion with reference to each other. Again this conception leads to the unity of the nature of inertia and gravitation.

It is to be noted, however, that a gravitational field can be replaced by a frame of reference having a uniform acceleration only within a very limited portion of space; about in the same way as we can think of a plane sheet of paper being in contact with a curved surface over only a very limited part of the surface. Nevertheless the principle of equivalence gives us the correct mode of attack to conquer the difficulties of the general theory of relativity. For as Einstein says in his Princeton lectures of 1921: "The possibility of explaining the numerical equality of inertia and gravitation gives to the general theory of gravitation, according to my conviction such a superiority over the conception of the classical mechanics, that all the difficulties encountered in the development must be considered as small in comparison."

In the general theory then we must do away with preferred systems of reference of any kind, the term 'gravitational field' involving all arbitrarily moving frames of reference of any kind.

Let us now consider one of the simplest of such fields present in case of a rotating system. Let K′ be a frame of reference whose x'_3–axis coincides with the x_3–axis of the system K at rest.

We put the question: Are the configurations of rigid bodies at rest relative to K′ (that is, moving with K′) in accord with Eculidean geometry?

As K′ is not an inertial system we do not know directly the configurations of rigid bodies with reference to K′.

Let us take a circle in the x'_1—x'_2 plane and a diameter of this circle. Further let us place a sufficient number of very small rigid rods of the same length along the circle and the diameter; then the ratio of the number in the circle to the number in the diameter come out equal to π. Let now the system K′ be rotated with uniform angular velocity about x'_3–axis . We will now find that more rods will have to be placed along the circle while none need be added to the diameter. This is easily explained; for the

rods along the circumference suffer a Lorentz contraction while those along the diameter do not. The ratio of circumference to diameter now comes out greater than π. From this follows that the laws of configuration of rigid bodies does no longer conform to Euclidean geometry. Again if we place two synchronous clocks, one in the center and one in the circumference of the system K′ in uniform rotation, the latter will go slower if observed by someone at the center. From this follows that space and time can not be defined with respect to K′ as they were in the restricted theory.

According to the principle of equivalence K′ is here also to be considered as a frame of reference at rest with respect to which a gravitational field is present. (Field of centrifugal force). We must then come to the conclusion that a gravitational field influences and in fact determines the metrical properties or the 'metrics' of the time-space continuum. If then the laws of configuration of rigid bodies are to be expressed geometrically, the geometry is non-Euclidean.

A similar situation presents itself in the consideration of general two-dimensional surfaces as intimated above. On the plane, Cartesian coordinates x_1, x_2 will suffice to measure any portion of the same by means of rigid measuring rods; not so on the surface of an ellipsoid for instance. Gauss introduced curvilinear coordinates to overcome the difficulty, which satisfying the condition of continuity are wholly arbitrary otherwise. (flexible threads take the place of shord rigid rods). Later these coordinates were related to the metrical properties of the surface. Then Rieman extended the dimensions to any number, establishing infinitesimal geometry to n dimensions in which the generalized Pythagorean theorem holds. Applying this to our space-time frame of reference of the general principle of relativity we have the arbitrary coordinates x_1, x_2, x_3, x_4 numbering uniquely 'world points' and the invariant interval between two such points.

$$ds^2 = g_{\mu\nu}\, dx_\mu\, dx_\nu \qquad G_{\mu\nu} \text{ from } 1\text{—}4 \quad g_{\mu\nu} = g_{\nu\mu}$$

in which the $g_{\mu\nu}$ describe with respect to the coordinates the metrical relations of the continuum and at the same time the gravitational field.

The above expression expanded would become:

$$ds^2 = g_{11}dx_1^2 + g_{22}dx_2^2 + g_{33}dx_3^2 + g_{44}dx_4^2 + 2g_{12}dx_1dx_2 + 2g_{13}dx_1dx_3 + 2g_{14}dx_1dx_4 + 2g_{23}dx_2dx_3 + 2g_{24}dx_2dx_4 + 2g_{34}dx_3dx_4$$

The g's are functions of the infinitesimal coordinates; mathematically they are quadratic functions of the infinitesimals.

The $\mu\nu$'s may be represented by the symmetrical array:

11	12	13	14
21	22	23	24
31	32	33	34
41	42	43	44 ; but as the $\mu\nu$'s $= \nu\mu$'s

we need only:

11	12	13	14
	22	23	24
		33	34
			44 which are the double subscripts

occurring in the above expansion.

In case of the absence of a field of force, the equation becomes that of the restricted theory:

$$ds^2 = -dx_1^2 - dx_2^2 - dx_3^2 + dx_4^2$$

in which x_1, x_2. x_3 are imaginary space coordinates and dx_4 the real time coordinate that can be measured directly by means of a clock. The g's in this case are represented then by the following array:

—1	0	0	0
0	—1	0	0
0	0	—1	0
0	0	0	+1

As a concrete example we will consider the transformation to rotating axes, the rotating system mentioned on page 278.

The infinitesimal space-time interval of the frame of reference is represented by:

$$ds^2 = -dx^2 - dy^2 - dz^2 + dt^2$$

let x_1, x_2, x_3, x_4 be any functions of x, y, z and t then:

$$dx = \frac{\partial f_1}{\partial x_1} dx_1 + \frac{\partial f_1}{\partial x_2} dx_2 + \frac{\partial f_1}{\partial x_3} dx_3 + \frac{\partial f_1}{\partial x_4} dx_4 \ . \ . \ .$$

and this will lead us to the expressions holding in the general theory namely:

$$ds^2 = \underset{\substack{\mu\ \nu \\ 1\text{-}4}}{g} \quad \text{as given above.}$$

The relations for transforming to rotating axes are:

$x = x_1 \cos \omega x_4 - x_2 \sin \omega x_4$
$y = x_1 \sin \omega x_4 + x_2 \cos \omega x_4$
$z = x_3$
$t = x_4$;

and we have:

$$dx = \cos\ \omega x_4 dx_1 - \sin\ \omega x_4 dx_2 - \omega(x_1 \sin\ \omega x_4 + x_2 \cos\ \omega x_4)dx_4$$
$$dy = \sin\ \omega x_4 dx_1 + \cos\ \omega x_4 dx_2 + \omega(x_1 \cos\ \omega x_4 - x_2 \sin\ \omega x_4)dx_4$$
$$dz = dx_3$$
$$dt = dx_4$$

Substituting in the equation for ds^2 we have:

$$ds^2 = -dx_1^2 - dx_2^2 - dx_3^2 + [(1-\omega^2)(x_1^2+x_2^2)]dx_4^2 + 2\omega x_2\, dx_1\, dx_4 - 2\omega x_1\, dx_2\, dx_4$$

Comparing this with the expression for

$$ds^2 = g_{11}dx_1^2 + g_{22}dx_2^2 \ldots .$$

we get the values of the g's:

$$g_{11} = -1$$
$$g_{22} = -1$$
$$g_{33} = -1$$
$$g_{44} = [(1-\omega^2)(x_1^2+x_2^2)]$$
$$2g_{14} = 2\omega x_2$$
$$2g_{24} = -2\omega x_1$$

or the array is:

$$\begin{matrix} -1 & 0 & 0 & \omega x_2 \\ 0 & -1 & 0 & -\omega x_4 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & [(1-\omega^2)(x_1^2+x_2^2)] \end{matrix}$$

If we put: $\frac{1}{2}\omega^2(x_1^2+x_2^2) = \Omega$ then $g_{44} = 1 - 2\Omega$, represents the potential of centrifugal force, or a special type of gravity-potential.

Although the g's represent the metrical properties of the space-time continuum, we do not ordinarily look upon them as the field produced by rotating axes. We have other means like the gyro-compass or Foucault's pendulum to present such a field to our minds, yet the field is nevertheless defined by the g's and as seen especially in this case, by the g_{44}.

It must therefor be possible to represent the gravitational field in the specific sense by the g's, and Einstein has accomplished this by finding the differential equations satisfied by the g's representing this field. These differential equations for the generalized potential express the law of gravitation of Einstein just as the Newtonian law of gravitation is represented by:

$$\Delta^2\varphi = 0$$

It is important that the two-fold meaning of the g's be fixed in mind, namely, that they on the one hand express the metrical properties of space and on the other the potential of a field of force. In the absence of such a field of force the field is called Galilean—in which the law of inertia holds and the g's are represented by the array:

$$\begin{matrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & +1 \end{matrix}$$

It is hardly to be attempted here to go into details in deriving Einstein's law of gravitation, as that would involve the development of tensor analysis; but a few interesting facts in connection with the same should be mentioned here.

The complete mathematical analysis had been developed before Einstein attacked the problem. The theory of tensors by Riemann and Christoffel in 1867 and 1896 respectively and by Ricci and Levi Civita in 1901 in connection with the theory of surfaces, non-Euclidean geometry and absolute differential calculus including tensor analysis lay ready at hand.

As an example of tensors may be mentioned the fundamental covarient tensor $g_{\mu\nu}$ of the second order, used in connection with the transformation to rotating axes above. A tensor of the first order is identical with a vector of common vector analysis, and a tensor of zero order is identical with a scalar. Like vectors, tensors are represented by their components. Tensor analysis represents a very powerful tool for the development of the general theory of relativity, symbolizing the laws of nature in connection with a space-time frame of reference that are consistent with the laws of relativity.

Mathematical and Experimental Tests of the General Theory of Relativity

Before going into this matter it is well to keep in mind that we are not concerned with the 'proof' of the theory. Einstein himself has said, that no amount of experimental demonstration could prove him correct; and that a single experiment could at any time prove him incorrect.

We are concerned only with a theoretical, experimental or observational test of phenomena predicted on the basis of the

theory. Only three of these tests have so far been suggested by Einstein as possible; the fact being that Newton's law is a very close approximation to Einstein's law, the latter being capable of degeneration into the former.

Tests.

First: To account for the inconsistence of the observed advance of the perihelion of Mercury with the theoretical value based on Newton's law of gravitation.

That theoretical astronomers did not know what to do next concerning the discrepancy after trying various schemes follows from the words of Simon Newcomb in his 'Astronomical Constants': "In case where our ignorance is complete all hypotheses which do not violate known facts are admissible." But there was no hypothesis that could make goood.

According to observation the line of apsides of the orbit of Mercury revolves in the direction of motion of the planet about the Sun through an angle of 574 seconds of arc in a century. The angle calculated from the perturbations of the planets accounted only for about 531″ leaving a remainder of 43″ that could not be accounted for.

Einstein's calculations based on his theory of gravitation showed that the Sun's gravitational field at Mercury produced the additional 43″ per century required. The effect of the Sun's field on the other planets according to the same law is quite small, on account of their distance from the Sun, amounting to about 8″ in the case of Venus, about 4″ in the case of the Earth and still smaller amounts in case of the remaining planets. The striking feature of the calculation is the absence of any adjustable constants in the formula used. The only constants appearing are the period of the planet, T, the semi-major axis of the orbit, a, and the eccentricity, e.

Second: The curvature of rays of light coming from fixed stars and passing near the Sun, due to the gravitational field of the latter.

In the first place it follows from the general theory that light travels slower in a gravitational field than in a region devoid of such a field, moreover its path is not a straight line the equation of the geodesic being:

$$\delta \int ds = o$$

or the geodesic in a field of force is curved; the amount of curva-

ture depending on the field strength in the region of the path.

Again a ray of light or electromagnetic radiation possesses energy and hence the equivalent of 'mass,' consequently it is acted upon by a gravitational field, the amount of bending depending on the strength of the field from point to point of the path, and varying besides inversely with the distance from the centre of the Sun. At the surface of the Sun the deflection is predicted to be 1".75

Why there should be a deflection due to the gravitational field of the Sun may be seen by referring back to the principle of equivalence in connection with the hypothetical box-experiment.

Let us imagine the man to one side of the box firing a bullet percenticular to the vertical wall of the box. The bullet will pass through the box and out on the other side. In the space out side it will fly in a straight line being in a field free of force; inside the box, however, it will be deflected downward. Interpreted by the man in the box as due to a gravitational field and by the man outside due to the upward acceleration of the box. In the case of a ray coming from a star the ray takes the place of the mass of the flying bullet, by virtue of energy of radiation having the equivalent of mass; and the accelerated box being equivalent to a gravitational field, taking the place of the Sun's gravitational field. The analogy is of course only approximate, the 'equivalence' holding only within the confines of the box.

We will now give the results of the observational test of the

Light Deflections Observed at the 1919 and 1922 Eclipses

Eclipse	Expedition	Telesc.	No. of plates	No. of stars	Ang. dist. fr. Sun	Range of deflect	Res.	P. E.	Observers
1919	Sobral	4", 19'	7	7	0.°5–1.°5	0."88–0."32	1."98	±."12	Dyson
May 29	Sobral	8", 11'	16	6–12	0. 5–1. 5	0. 88–0. 30	0. 86	±. 10	Eddington
	Principe	8", 11'	2	5	0. 5–1. 5	0. 86–0. 30	1. 61	±. 30	Davidson
1922	Wallal	6", 10'	2	18	0. 5–2. 6	0. 85–0. 18	1. 74	±. 30	(Chant / Young)
Sept. 21	(Cordillo / Downs)	3", 5'	2	14	0. 6–2. 9	0. 83–0. 16	1. 77	±. 30	(Dodwell / Davidson)
	Wallal	5", 15'	4	62–85	0. 5–3. 4	0. 85–0. 15	1. 72	±. 11	
	Wallal	4", 5'	(3)*	135–139	0. 5–10. 4	0. 85–0. 04	----------		(Campbell / Trumpler)

* 4th plate not yet reduced.

Prediction by Einstein's Theory 1."75

The agreement with prediction is especially good in connection with the 1922 eclipse. The last 4 plates, only 3 being reduced so far, were especially taken to test the 'distance law.' For this

purpose a wide-angle lens (of short focal length) was chosen giving a field of great range, recording stars at from 5° to 10° away from the Sun, by means which that law was also confirmed, the residuals, observation minus theory, coming out extremely small.

Third: We have pointed out in connection with a field of centrifugal force that a clock placed in such a field loses time. The same would be true if a clock were placed in a gravitational field. Now an atom is a periodic mechanism comparable to a clock. Its period would be greater in the gravitational field of the Sun than in that of the earth. As a consequence of this the spectral lines of a substance in the vapor envelope of the Sun would be shifted to the red as compared with the lines of the same substance produced on the earth. The relative displacement is about the same as that produced by a radial velocity of recession of 0.63 kilometers per second, being of the order of 0.008 Angstrom units measured in the region of λ=3883 Å lying almost within the errors of observations. Nevertheless the results of Evershed in 1918 and those of Grebe and Bachem in 1919 have offered considerable evidence in corroboration of the prediction; while at that time the findings of Prof. St. John of the Mt. Wilson solar laboratories were not confirmatory. In September 1923, however, in a paper read before the Astronomical Society of the Pacific he expressed himself as having come to the conclusion that he had confirmed the Einstein effect relating to the above shift of spectral lines; and that in the future a correction would have to be applied to spectroscopic measures.

At the last meeting of the National Academy of Science, (Science, May 16, '24) Prof. H. D. Curtis of Allegheny observatory reported recent measures of Drs. Burns and Meggers: "showing shift of lines very different from the simple and uniform amounts predicted by the relativity theory. Instead of all the lines being shifted by an equal amount to the red and that amount predicted by the Einstein theory, a very marked line-intensity factor is found. That is, for very faint solar lines there is little if any shift, and the amount of this shift increases as the wider and stronger lines are used." Then follow numerical results showing the above; and finally, after some further remarks along the same line, the following conclusion: "Accordingly the authors regard these results as a negation of one of the so-called proofs of the theory of relativity."

In the judgment of the writer the above statements are hardly conclusive. Similar findings were reported by Prof. St. John of Mt. Wilson in the Astrophysical Journal Vol. 41, p. 62, 1915. And Prof. St. John in a private communication to the writer says quite correctly: "Curtis' results showed the long recognized difficulty that strong (high-level) lines of iron show a shift to the red greater than the Einstein prediction, and the weak lines (low-level) a red displacement smaller than that required by relativity. This is at the center of the disk and the small differences from calculated values taken care of by radical currents of small cosmic velocities, upward near the photosphere and downward at very high levels. I see no way in the absence of pressure to account for these displacements without calling in relativity. At the edge of the disk the currents are no longer in the line of sight. The result at the limb is then a red displacement for both strong and weak lines of the full relativity value and a little more, this small excess being taken care of by differential scattering which produces a slight asymmetry on the red edge. There is no interpredation that will account for the red displacement at the limb, other than relativity."

These words coming from the greatest authority of solar spectroscopy in America and one of the greatest in the world, leaves hardly any doubt that also this last prediction has stood the experimental test of astrophysics.

The test of this prediction and a confirmative outcome is of especial importance for two reasons. The first is, that Einstein himself maintains that 'his whole theory of gravitation stands or falls by the success or failure of this test'; second that, as Eddington has pointed out, 'if the displacement of solar lines be confirmed, it will be the first experimental evidence that Relativity holds for quantum phenomena.'

Now a last word as to 'gravitation' itself. Newton assumed 'absolute space' and 'matter' essential and besides this the concept of force acting between any two portions of matter in space. He himself has said, that it is absurd to think of force acting between two bodies through empty space; but the inverse square-law works, to at least a very close degree of approximation, but it nevertheless remains 'unreasonable.' In Einstein's theory 'gravitational force' has no place as a fundamental concept! It is the 'gravitational field' analogous to the electrical and mag-

netic, or better, the 'electromagnetic field' that is the physical reality; and this finds its expression as a metric property of space; mathematically represented by a set of differential equations involving twenty functions which finding their place in these equations express the curvature of the space-time continuum just as the Rieman 'curvature components' do in three dimensional space. If these twenty functions were zero, either the gravitational field would not be present, according to Einstein, or it could be 'completely' removed by a proper change of frame of reference. But we know that it can not be removed except within a very small region. This means that there are some essential 'curvature components' that can not be done away with by any choice of frame of reference; in other words the twenty curvature components are not 'individually' equal to zero. Einstein now reasoned that there must be some mathematical relation corresponding to the physical properties of space-time independent of the choice of frame of reference; and here it is the genius of Einstein that makes the brilliant guess that certain 'linear functions' of these curvature components are zero outside of matter and equal to a similar group of functions within matter involving internal dynamical properties of matter itself, of which the electron theory will give us more and more information as time goes on.

The attempt has been made by Weyl and others to include the electro-magnetic field side by side with or intrinsically connected with the gravitational field, but Einstein says that such considerations will not bring us nearer to the true solution of the problem. According to him a theory in which the gravitational field and the electromagnetic field enter as an essential entity would be much more preferable.

Prof. Einstein has published a paper in the "Sitz. Ber. d. Preuss. Akad." 1923, in which he presents this master problem of "gravitation-cum-electro-magnetism" expressed in forty differential equations characteristic in containing besides the fundamental covariant tensor $g_{\mu\nu}$ of the gravitational field the fundamental covarient tensor $F_{\mu\nu}$ of the electromagnetic field, including of course also matter, as we usually do not think of it, namely as nuclei or centres of electromagnetic action; or electrons and protons exhibiting respectively negative and positive charges of electricity.

We may hope that also here experimental tests may present themselves that may bring us nearer to the goal of comprehending the true nature of matter and energy, or more likely the two as one, and that one would have to be energy.

The author acknowledges as his principal source for the above the "Princeton Lectures" of Prof. Einstein, whose definitions will be recognized. The section on a rotating system of coordinates is taken from Prof Eddington's "Report."

SOME PROBLEMS OF TAXONOMY

A. W. LINDSEY

During the past the pronounced tendency of systematists to do little more than describe and name different species of plants and animals was a prevalent and largely necessary evil. Even so, the work of taxonomists was indispensable in the biological sciences, and now that it is no longer without adequate foundations, it can be of inestimable value. Its value, of course, must depend to a high degree upon its usefulness to other branches of science, but if we except the field of medicine, none of the other branches have great intrinsic worth.

During the last thirty or forty years the classification of animals has been placed upon a sound phylogenetic basis which renders the work of a thorough systematist of the present day of much greater importance than the mere description and naming of species. Account must now be taken of the morphology, ecology and physiology of organisms, of paleontology where it serves, and possibly of genetics. The discoveries of geneticists, so far, appeal to the writer as incapable of wide application to the problems of taxonomy, although they may easily furnish many checks on the relationships of species and their subdivisions. The modern systematist must be well grounded in all branches of biology, and his work, in order to be reasonably accurate and useful, must express the deductions of such training.

The dignity of taxonomy as it should be, then, is scarcely to be denied, but it is all too true that many taxonomic works of the present afford more than one opening for criticism. As a systematic entomologist and a devotee of the Order Lepidoptera, the writer has noted with many misgivings certain phases of this matter which it is his purpose to discuss in this paper. Most important of these is the limitation of systematic divisions below the genus, including the questionable practice of naming slight variations. Closely related to this topic are the conflicting methods of naming such divisions, and last of all, one of the most vexatious questions in the classification of animals is that of the stabilization of generic names.

I. The Species Concept.

The question of the existence or non-existence of species in nature is one of such age that some hesitation must be felt in attacking it. However, no discussion with which the writer is familiar furnishes a satisfactory foundation for a practical system of classification. All treat the species as a thing capable of rigid definition, either actual or imaginary, and herein their weakness seems to lie. In entering upon a discussion of this point it will be well to consider some of the material which it concerns.

In the insects, and in the Lepidoptera perhaps as much as in any other order, we are dealing with a highly successful group which has ramified considerably in adapting itself to various conditions of environment, yet still includes relatively generalized forms. These are capable of becoming modified further in response to changes of the habitats which they now occupy. As extreme examples of the specialized types, *Feniseca tarquinius* Fab. and the myrmecophilous Lycaenidae may be cited among the Diurnals. *Euxoa* among the moths and *Argynnis, Melitaea* and *Euphydryas* are good examples of the more generalized genera. It must be clearly understood that all of these forms are specialized in some degree, as, of course, all existing Metazoa are.

Such forms as *tarquinius* may be passed over briefly. It seems that everyone should agree in accepting them as well defined, natural units to which the designation species is properly applicable. In the writer's opinion there are many such species whose existence as natural entities cannot seriously be questioned. Powers applies this idea of species in a sweeping way. He states that "The whole spirit of modern biological research seems to the writer to demand the conception of species as realities,—not all alike, in their reality, of course."[1]

In contrast to this view, Montgomery says that "in Nature occur only individuals, as was clearly pointed out by Lamarck, and is generally acknowledged at the present time, species and other groups being arbitrary concepts."[2] By an extremely rigid and inclusive application of this view, it may possibly be regarded as

[1] Studies from the Zool. Lab., U. of Neb., no. 95. Reprinted from the *American Naturalist*, xliii, 1909.

[2] Montgomery, On Phylogenetic Classification, Proc. Acad. Nat. Sci. Phil. 1902, p. 193.

affecting all existing life, for the possibility of variation within some limit of degree and time is a fundamental provision of our theories of phylogeny. These facts, however, are axiomatic, *viz.*, that an organism's power to vary and to adapt itself to change of environment decreases with every progression, in whatever direction, from the primitive condition of its ancestors, and that there is an ultimate point beyond which the process of its evolution cannot go. That such a point exists, a point at which the species itself enters a state of senility wherein any considerable demand for further adaptation can result only in extinction, is abundantly proved by the dinosaurs, pterodactyls, and other extinct forms of the past. Among existing animals such forms as the birds of paradise and the head fishes appear to be senile to an appreciable degree, and less conspicuous examples are found in the Lepidoptera already mentioned. Such forms may easily be recognized as natural entities.

For the purposes of a practical system of classification it is necessary to reach some basic idea of our unit and the way that it is to be applied, and this idea must necessarily be applicable to the entire subkingdom, if not to all living organisms. Many of the so-called species of the present are in a state of senility as pointed out, some are primitive but constant, while others are either primitive or generalized, and very actively variable. It is obvious both from past experience and from a logical consideration of these facts, that the application of a single rigid concept to the limitation of all of these groups is a difficult task. Here the neglected element of time enters. Combined with senility, it furnishes us with an ideal of the species as a natural unit which we may define as follows: *A group of individuals may exist as a natural entity at any period of time in the phylogeny of the line to which it belongs when the specialization of this group has proceeded to such a point as to preclude (a) the production of a marked degree of future modification and (b) discernible intergradation with other similar units, and in this state may be regarded as an ideal species.*

After the elimination of such forms there remains the immense number of living organisms which are not, at present, divided into rigidly delimitable species. Perhaps after the passage of many thousands of years these will have resolved themselves into such species as were defined in the last paragraph, but here again time is the important factor. These variable groups must

be treated as they are at present, and together with groups of all other degrees of stability. The transition is so gradual that different terms cannot be used to designate conveniently the various conditions, therefore it becomes necessary to arrive at an accurate idea of the variable application of that now in use, namely, species. Since, in a consideration of phylogeny, the present must necessarily refer to geologic time, the result may well apply to all scientific results of the past, and to the future beyond logical prediction.

In order to be compatible with the ideal species, "species" selected from the more variable forms should be *definitely delimitable groups of individuals, regardless of the amount of variation included.* This is essentially the idea of Powers[1]. Montgomery expresses a very convenient idea of species, although with a very different intent, which may be used in this connection. This is found in his definition of a species as a "mental section of a line of evolution."[3] The opinion has already been expressed that these sections may be natural entities, and that in order to be properly regarded as species, they must be. In other words, in an hypothetical cross section of the phylogeny of all existing forms, the species are those elements which are definitely separable. When elements named as species in the past are found incapable of separation, they must be regaredd as divisions inferior to the species of this interpretation, and the species to which they belong should be sought in a "section" of greater extent. The accurate arrangement of any of these elements in our actual classification is, of course, fraught with considerable difficulty. Until our knowledge is more nearly complete and perfect we must expect constantly to revise our results; the careful and diligent study of an abundance of material—ideal conditions, to be sure,—may some day result in a classification of reasonable stability.

It is not the writer's purpose to present here a discussion of the problems of transmutation of species,[4] the influence of genetics on the species concept[5] or the methods of limitation of species,[6] which are taken up in the papers cited. It is proposed to suggest in this concept of species a basis for practical classification. By reducing the application of the term species to groups

[3] Montgomery, *op. cit.*, p. 206.
[4] Powers, *op. cit.*
[5] Davis, Species, Pure and Impure, *Science* lv, no. 1414, pp. 107-114, 1922.
[6] Montgomery, *op. cit.*

of individuals which are at the present time delimitable, without regard for the extent of variation embraced by any one, it should be possible for the average worker, as well as the specialist with extensive resources, to become familiar with the chief units of any division. The next difficulty is the treatment of the subordinate divisions of such extremely variable species as some of those included in *Euxoa*. In discussing this, although a degree of unwelcome complexity is thus introduced into the second part of this paper, it will be convenient to take up in rather intimate association the methods of subspecific nomenclature and the value of the various subdivisions.

II. Subspecific Divisions.

In the first topic of this paper the species concept was discussed, with the conclusion that the term species properly designates a natural entity consisting of a delimitable group of individuals. This was qualified by the addition of the element of time, recognizing that the species of the present are in varying stages of evolution, and that many of them may ultimately resolve themselves into more nearly ideal species. As the ideal species, senile forms which had run through their possible phylogenetic development were mentioned. The purpose of the second topic is the discussion of the subdivision of the more generalized and variable species of the present, and the nomenclature to be applied to their subordinate parts.

Formulating the problem as a generally applicable hypothesis, rather than as a specific case, let us consider the ways in which these variable groups have been treated. We may examine them as two hypothetical species, both variable. Each in its entirety may be regarded as a well defined "cross-section," the first made up of a number of fairly definite subordinate sections and the second of scarcely separable subordinate components. The two may be likened to a cellular tissue in comparison with a syncytium.

The first hypothesis finds many examples in existing species which occur in two or more forms, usually well marked. The early method of treating such species was to accept the form first named as the species and those discovered later as varieties. If an occasional specimen appeared showing a marked variation from the normal, it was, and still is, known as an aberration. Many of these bear names. This simple subdivision of species

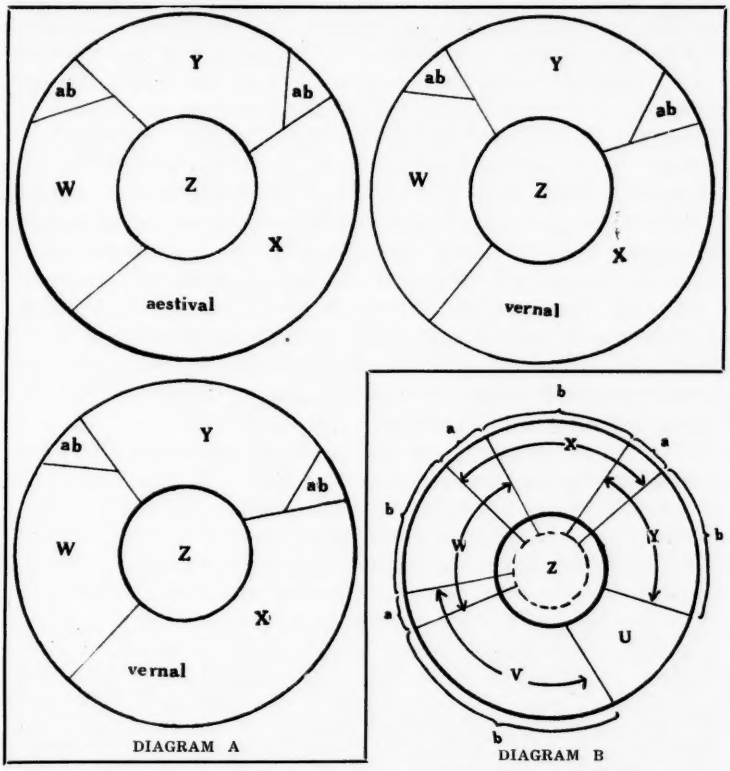
was long accepted as sufficient, but increasing inquiry into phylogenetic relationships has shown that with such an arrangement forms of indubitably different value are often accorded the same rank.

Some writers deny the right of the original specific name to stand alone if any named variations exist.[7] This makes necessary the use of a trinomial for the correct designation of any form of a variable species. The following paragraph by Hartert, Jourdain, Ticehurst and Witherby[8] is pertinent in this connection: "As the use of trinomials for subspecies—or better, geographical or local races—does not seem to be generally understood, it may be here explained that when a species is divided into two or more races, or when two or more species are grouped as races of one species, then each of these races must have a trinomial appellation. It is impossible to say which is the oldest or parent form, therefore the first named race of all those grouped under one species is arbitrarily taken as the typical race, and its name becomes that of the species."

Other writers have adopted a very logically conceived division of the variations into forms and geographical races, a method of subdivision which was very successfully employed in the most recent check list of North American Lepidoptera.[9] In this list Dr. McDunnough also drew on the work of Mr. Roger Verity[10] for another form of subdivision, the seasonal generation, exemplified in *Pieris napi* Linn. This species is listed in our fauna with seven races, two of which are accompanied by named aestival generations, and in addition to these seven, three vernal generations with accompanying aestival generations. According to the lettering used, the vernal generations are ranked with the races. This method of division, though it undoubtedly has its faults, appears to be by far the most accurate indication of phylogenetic relationships yet devised for expression in a linear series. We must recognize the existence of geographical races, of which an excellent example, based largely on genitalic structure, is found in *Hesperia tessellata* race *occidentalis* Skinner.[11] Likewise the existence of seasonal generations has been proved beyond doubt,

[7] In Lepidoptera, see Rothschild & Jordan, Revision of the Sphingidae.
[8] A Hand-List of British Birds, pp. ix-x, 1912.
[9] Barnes & McDunnough, Check List of the Lepidoptera of Boreal America, 1917.
[10] Verity, Rhopalocera Palearctica.
[11] Barnes & Lindsey, *Ent. News* xxxii, 79-80, 1921.

most conspicuously in the Indian fauna of the wet and dry seasons, but quite evidently in the various forms of *P. napi* Linn. Aberrations are known to every systematist and the name is self explanatory. Varieties have been confusing in that the term has been made to include everything not nimotypical. In the check list mentioned the terms form and race have been substituted for



variety. A form is regarded as a variation occurring side by side with the nimotypical form, in contrast with geographical races, which are variations occurring in a region distinct from that occupied by the nimotypical form. This substitution seems to be so successful that it permits the discarding of variety as an obsolete term. In order to present the consideration of these subdivisions more graphically I have drawn diagram A, assuming

for its basis an hypothetical species showing all of the variations in question. This might well be regarded as a part of the evidence furnished by *P. napi,* but introduces elements not observed in that species.

In this diagram the three circles represent three hypothetical cross sections of the species, each of which may be regarded as a somatic generation. The central element in each of these may represent the basic form of the species, and may, for convenience, also be regarded as nimotypical. The axial line through the three z elements represents the main line of the germplasm, although the complete connection of the three generations must necessarily be regarded as the cylinder of which they are cross sections. That part of the three generations not included in the nimotypical form is divided into a geographical race w, a form y, and a third element, x, including alternating vernal and aestival generations. W and x are assumed to show aberrations. In the natural state, the probability is that w would produce only w, although the available evidence suggests that artificial change of environment would lead to the production of each from the other. Y and z, occurring in the same region, would be produced from each other. As worked out by Verity in *P. napi,* x may represent a definite line.

Designating the genus as G, trinomial nomenclature would name these forms Gzz, Gzx, Gzy and Gzw. In the case of the second a puzzling situation presents itself. We have already chosen to apply to the entire species the name which has priority. If we continue this by assigning to one of the seasonal forms priority over the other, a complete designation of the latter involves the use of a cumbersome quadrinomial, and any minor variation which might receive a name would carry it one step further. Another difficulty with such a species is that a thorough analysis may give us a series of aberrations, such as Gzw ab. and Gzy ab., which are distinguished at least in part by the same characters and named only upon a basis of their origin. This is not common, of course, but in the insects is by no means hypothetical.[12] Can it possibly be regarded as necessary for the purposes of classification to toil with such a series of names? No matter whether such an aberration is among the progeny of w, or y, it is the product of the same germ plasm, apparently in

[12] Reiff, The Lepidopterist i, 15, 1916. Dyar, The Lep. i, 31, 1917.

response to the same stimuli, and as such may be designated by reference directly to the nimotypical form with at least sufficient minuteness for ordinary use. For genetic considerations these minor forms may be treated without naming, as will be mentioned later. We should note, before leaving this matter, that in most cases such divisions as have been discussed are based upon differences of color and pattern, which are apparently quite directly responsive to changes of environmental conditions. When lines such as w, x and y occur, their existence is probably due to slight normal differences of environment, and we must recognize that the fluctuations of meteorological conditions might easily result in temporary similarity of these normally different conditions of existence, such as would produce forms and aberrations like those under discussion.[13] If the similarity of these is complete, they may certainly be named as one; if partial, as in the case of the *Catocala amica* forms mentioned in the paper last referred to,[12] they are certainly not worth separating from their parent forms.

The problem presented by this type of variation, involving only a moderate number of forms in any species, and these fairly well marked, is comparatively simple. It is essential, in the first place, to have a name which may be applied definitely to the entire species, and there is no serious objection to the rule of priority now applied. In a few cases, as *Papilio glaucus* Linn., a subordinate form has priority. When, as in this case, the nimotypical form occurs in only one sex, the necessity for modification is strongly suggested, but the simple application of trinomial nomenclature is an ample measure.

With regard to the use of polynomials to indicate the complete relationship of the ultimate division with the nimotypical form, personal opinion must enter. As matters stand at present this unavoidably leads to cumbersome combinations. Neither modern system of nomenclature eliminates these, yet these systems have points of value which we should be reluctant to sacrifice. If the pronounced tendency were not present among entomologists—I feel inclined to say lepidopterists in particular—to

[13] In dealing with such superficial characters as distinguish most minor forms and aberrations, the question of reversal can hardly enter. More fundamental modifications such as would involve this question do not, in any case known to the writer, furnish the basis for such a complexity of nomenclature as is here discussed.

name the most minute variations, I should favor the use in this field of a combination of the trinomial method with the subdivisions of Barnes and McDunnough's Check List, but because of the existing tendency, such a course seems to defeat the object of systematic science. What is the use of a named race, form or aberration which is so rare or so obscure that only a few specialists in the country can determine it? Such fine ramifications can be traced out without the application of names, if, indeed, they are worthy of notice, and the studies recorded still be made available to the few who will carry them on. The names applied to minor forms are usually an inert encumbrance of the nomenclature, at the best, and are a hindrance to many in a branch of science which should be efficiently helpful to all.

This brings us to the question of the actual value of variations. I think that no one will fail to agree that such a conspicuous thing as *Vanessa antiopa* ab. *hygiea* Heyd. is worthy of a name, or that *Poanes hobomok* ♀ form *pocahontas* Scud. is quite distinct from the normal female and worthy of independent designation. In the later, however, there has recently appeared another named division, *Poanes hobomok* ♀ form *pocahontas* ab. *friedlei* Watson.[14] Some of our leading lepidopterists have been guilty of actions almost as objectionable, but in this case a serious weakness is found in the fact that the unique type was reared under artificial conditions. The type itself is described as an abnormally dark *pocahontas* with reduced maculation—characters which go hand in hand in the Hesperiidae. It was reared with one other specimen, a male, which is also noted as exceptionally dark. Add to this the fact that the conditions of rearing might reasonably be expected to favor melanism, and no conclusion seems possible save that the name is utterly useless. In my series of thirty or forty specimens of *hobomok* I have traced a gradual transition from the normal female to very dark melanic forms in which three or four stages equal in value to *friedlei* can be distinguished. What possible good could come of naming them?

No doubt many names such as that discussed in the last paragraph are applied by men who have too little material for a proper appreciation of the general characteristics of a species. Diagram B will serve to illustrate our consideration of this prob-

[14] Watson, *Jn. N. Y. Ent. Soc.* xxviii, 232, 1920.

lem, which is intimately associated with the second of our hypothetical species. However, it might well be based on such a species as *Euxoa tessellata* Harris or *E. messoria* Harris. The entire diagram represents the hypothetical cross section, the species under consideration. Z, the inner circle enclosed by an unbroken line, may again be taken as the basic and nimotypical form, overlapped as represented by the dotted circle, by each of the variations v, w, x and y. These variations, whether races or forms, may also overlap each other as shown. Obviously, to a man possessing series or specimens only from the sections b of these variations, they would seem abundantly distinct and deserving of names. By supplementing this material with other specimens from the a zones he would at once perceive their intergradation and the necessity for great circumspection in their treatment. Such variations appear to be incipient forms, possibly incipient species, but at such an early stage in their evolution that their right even to be named may be seriously questioned. All belong to species z, and to any but a laboratory scientist or a student of heredity the simple binomial Ga would be much more useful that a long series of named, intergrading forms. The work done in late years on heredity in *Drosophila* is an excellent case in point.[15] What a galaxy of named *Drosophila* forms we should have if the geneticists showed the same tendencies as some of our systematists! Another unfortunate feature of such species is that they may produce a distinct form such as u. The probable treatment of such a form would be assignment to a rank equal to that of v, w, x and y, although it alone might deserve to be called a form or race. I venture the assertion that many species of our present classification, at least in the order Lepidoptera, will fit more satisfactorily as subdivisions in such a classification as this than in their present arrangement. Mr. F. H. Benjamin has already done an excellent piece of work on this basis in the genus *Lampra* Hübner (*Rhynchagrotis* Smith).[16]

Although, as is natural, the foregoing considerations have been illustrated by mention of insects whose study gave rise to them, an attempt has been made to formulate them in such a general way that each individual may adapt them to his own fund of

[15] Morgan *et al.*, Mechanism of Mendelian Heredity, 1915, and other works.

[16] Benjamin, F. H., A Study of the Noctuid Moths of the Genera Lampra Hbn. and Cryptocala gen. nov., Bull. S. Cal. Acad. Sci. xx, part 3, 1921.

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knowledge. They propose to show that the most satisfactory and accurate system—or systems—of nomenclature yet proposed has become a burdensome vehicle under present conditions,[17] but that this fault is due rather to the useless splitting of species into subdivisions of increasing minuteness than to any defect of the system itself. If only the workers who take delight in naming minute variations would curb this tendency or transfer their affections to other fields! Considering again the science of entomology, the biological and ecological study of insects supplies an inexhaustible and intensely interesting field. Moreover it is available on every hand, it does not require the formation of troublesome and expensive collections and libraries, and ones activities can be adapted to such apparatus as he can secure. It is essentially the field for the individual worker, wherein he may do accurate and valuable work if he only will.

III. The Stabilization of Genera.

A very troublesome phase of systematic work is the instability of nomenclature. Three classes of names are involved. *viz.*, specific and minor, generic and subgeneric, and those of major divisions. The first have caused very little trouble, for the simple recognition of priority is the sole requirement of all taxonomists save a few classical purists. The last have also been the source of little dispute. Generic and subgeneric names, however, are the source of infinite difficulty, and offer a problem which seems little nearer to solution today than a decade ago.

When a writer, in describing a genus, fixes its type, no misinterpretation can be made save through the improper association of species, which is outside of the pale of nomenclature. When a genus is erected to contain a single species this logically becomes its type and the case is equally clear. It is the genera described before the necessity of type fixation was recognized, usually to include a motley aggregation of species, which cause so much trouble.

The difficulty of fixing the types of such genera has long been recognized, and several codes have been published for the direction of this work. Of these the writer feels competent to discuss only those for the use of entomologists, since it is with these

[17] I am indebted to my friend and colleague, Dr. T. C. Stephens, for the information that when the trinomial system was originated, this ultimate difficulty was suggested by British Ornithologists.

alone that he has had practical experience. The earliest which we need to consider is that of Walsingham and Durrant.[18] This code formulates the method of fixing the types of genera which was in common use until the present century, and appears still to be favored by some European scientists. The most important principle involved is its acceptance of restrictions. In all codes the first provision is that the type shall be selected from among the species originally included in the genus,[19] and this is the only restriction now generally accepted as affecting the fixation of the type. The rules formulated by Walsingham and Durrant, however, express the principle so widely followed in the past, providing that if any writer used the genus subsequent to its description, and eliminated part of the originally included species, the type must be selected from those of the originally included species which he retained in the genus. In some cases this may be very reasonably applied, but it is weak, and hence scarcely to be considered as a generally applicable rule for the following reasons: First, in the early days of entomology, works covering the entire animal kingdom, yet of some scientific pretension, were often published. Obviously such works could not attempt to mention every known species unless they were purely systematic, hence only a few, or even one, was mentioned as an example of each genus. No intention of the writer to restrict the genera by such means can reasonably be assumed, yet such a citation of a single species in illustration of a genus has been taken as a valid fixation of the type. A good example is the genus *Hesperia* Fab. This genus originally included all of the Lycaenidae and Hesperiidae. Cuvier mentioned it, citing *malvae* Linn. alone as an example.[20] It is argued by some writers that this action fixes the type, but it is quite clear that the inclusion of this particular species was incidental. Thirty-nine years later another work of Cuvier made the same citation, with a footnote which indicates that his use of *Hesperia* was intended to be identical with that of Fabricius.[21] A second weakness with these restrictions is that they may be due to the fact that the restricting work dealt with only a limited fauna, or a certain collection, as in the case of

[18] Lord Walsingham and J. Hartley Durrant, Rules for the Regulation of Nomenclature, London, 1896.

[19] The International Rules provide also for the designation of types of genera originally described without included species.

[20] Cuvier, Tabl. Elem. 592, 1798. *Fide* Scudder.

[21] Cuvier, Animal Kingdom iv, 285, 1837.

Stephens' treatment of *Nisoniades* Hbn.[22] Scudder cast out Stephens' citation of *tages* alone under this genus for other reasons.[23] The one commendable feature of this rule is exemplified by the history of *Polyommatus* Latr. It seems reasonable that an author's modification of his own genus, especially when he treats all of the species concerned, should be recognized even without actual citation of a type. The difficulty here lies in impossibility of drawing the line at all if we wish to admit some restrictions, and if we admit all, it is impossible ever to predict the stability of the nomenclature. At any time some obscure work of no great value may be brought forward to play havoc with current usage.

The second code is that published by Banks and Caudell.[24] It is an admirably worded, clear and concise series of rules, and I am aware of but one objection to it, *viz.*, that it permits a species to be the type of only one genus, unless, of course, it should become the orthotype of a second through oversight. This is innately weak in that it robs actual type citations of their concrete value. Under such a rule the citation of the type is useless without a reasonable degree of certainty that it has not previously been cited as the type of another genus. The most important objection to this rule, perhaps, is that it conflicts directly with the International Rules.

These, the International Rules of Zoological Nomenclature, are the code which has by all means the best claim to the consideration of Zoologists. They were formulated by a committee of the International Congress of Zoologists, supposed to be representative of the various opinions obtaining on the subject of nomenclature in scientific circles. The rules are supposed to arbitrate differences of opinion and to arrive at the solution of greatest fairness to all concerned. One of our leading lepidopterists objects to following them on the ground that the congress was not truly representative, and that, in his opinion, certain type fixations not in accord with the rules are perfectly valid. An authority on another order of insects insists that Lamarck[25] did exactly the same thing as Latreille[26] in citing examples of genera, and that his citations should be regarded as valid type fixations, even though he did not use the word type. True enough, but this

[22] Stephens, Cat. Brit. Lep. 22, 1850.
[23] Scudder, Historical Sketch 228, 1875.
[24] Banks, N., and Caudell, A. N., The Entomological Code, 1912.
[25] Lamarck, Syst. An. sans Vert., 1801.
[26] Latreille, Consid. Gen., 1810.

is the very point on which it is necessary to have some authority such as the rules for a dependable common basis. The trouble through all the years has been just that which is made by these objections ,namely that every systematist has some favorite opinion to which he holds like grim death in the face of all opposition. Perhaps the writer too has favorite theories, and is championing them as radically by supporting the International Rules, but since this support occasions some extreme modifications of his own wishes in the matter of nomenclature, it can hardly be classed with the opinions here mentioned.

The desire to make exceptions is also displayed by even so great an authority as Dr. Handlirsch.[27] In his considerations of "Nomenklatur, Typen und Zitate," this writer formulates a series of rules of nomenclature drawn from various sources. He uses the International Rules for the fixation of genotypes, but in connection with his rule eight on priority, taken from the same source, proposes the following exceptions: "Ausgenommen von Umstossung auf Grund der Prioritätsregel sind nur solche Namen die ganz allgemein bekannt und in vielen Hand— und Lehrbüchern eingebürgert oder medizinisch, technisch bzw. ökonomisch von Bedeutung sind, sowie solche, auf Grund deren ein allgemein gebraüchlicher Name höherer Kategorien errichtet wurde, so dass durch Ungültigkeitserklärung des einen Namens auch die anderen umgestossen werden müssten." This is a component of the International Botanical Rules. It seems utterly impossible for such a rule to produce a uniform result in the hands of all systematists. Who shall say what degree of familiarity constitutes this right to stand? Moreover, what if a few usages do have to be changed? Many now common were made to supplant others of a more logical nature years ago, when the older usages had stood for decades. For example, *comma* was cited as the type of *Hesperia* by Dalman in 1816 *(fide* Scudder*)*, and the genus was used in this sense by competent writers as late as 1883, only to be removed at last to the place which it has since occupied with *malvae* as the accepted type.

As the International Rules stand, they are a satisfactory working basis for the stabilization of nomenclature, and should not be radically changed. By denying the use of the so-called restrictions, and by accepting as the type of a genus the first species

[27] Schröder, Handbuch der Entomologie iii, 83, 1913.

Stephens' treatment of *Nisoniades* Hbn.[22] Scudder cast out Stephens' citation of *tages* alone under this genus for other reasons.[23] The one commendable feature of this rule is exemplified by the history of *Polyommatus* Latr. It seems reasonable that an author's modification of his own genus, especially when he treats all of the species concerned, should be recognized even without actual citation of a type. The difficulty here lies in impossibility of drawing the line at all if we wish to admit some restrictions, and if we admit all, it is impossible ever to predict the stability of the nomenclature. At any time some obscure work of no great value may be brought forward to play havoc with current usage.

The second code is that published by Banks and Caudell.[24] It is an admirably worded, clear and concise series of rules, and I am aware of but one objection to it, *viz.*, that it permits a species to be the type of only one genus, unless, of course, it should become the orthotype of a second through oversight. This is innately weak in that it robs actual type citations of their concrete value. Under such a rule the citation of the type is useless without a reasonable degree of certainty that it has not previously been cited as the type of another genus. The most important objection to this rule, perhaps, is that it conflicts directly with the International Rules.

These, the International Rules of Zoological Nomenclature, are the code which has by all means the best claim to the consideration of Zoologists. They were formulated by a committee of the International Congress of Zoologists, supposed to be representative of the various opinions obtaining on the subject of nomenclature in scientific circles. The rules are supposed to arbitrate differences of opinion and to arrive at the solution of greatest fairness to all concerned. One of our leading lepidopterists objects to following them on the ground that the congress was not truly representative, and that, in his opinion, certain type fixations not in accord with the rules are perfectly valid. An authority on another order of insects insists that Lamarck[25] did exactly the same thing as Latreille[26] in citing examples of genera, and that his citations should be regarded as valid type fixations, even though he did not use the word type. True enough, but this

[22] Stephens, Cat. Brit. Lep. 22, 1850.
[23] Scudder, Historical Sketch 228, 1875.
[24] Banks, N., and Caudell, A. N., The Entomological Code, 1912.
[25] Lamarck, Syst. An. sans Vert., 1801.
[26] Latreille, Consid. Gen., 1810.

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actually designated by the word type or an equivalent of unmistakable meaning, whether or not it is already the type of another genus, they make it possible to eliminate much historical work in fixing genotypes, and to arrive at a definite result with the greatest possible degree of certainty that no pertinent matter has been overlooked. The chief source of trouble in the rules seems to be the arbitrary limitation of valid type fixations to those in which the word type is used. Some argue that in French this word does not have the same meaning as in English, but according to all available dictionaries it has the proper meaning, among others, even as in English it may mean only a representative. Any objection to the use of these rules, however, is weak. Its purpose must ever be the preservation of some familiar use of terms, and *no system can be applied to zoological nomenclature as a whole which will not overthrow some such usage.* Moreover some arbitrary rule is necessary, advanced and supported by authority, to override the multitude of personal opinions which will otherwise never find a common ground. Nomenclatorial research is a fascinating pursuit, but it cannot be said to advance scientific knowledge an inch. It should be settled definitely for all time, and the writer does not hesitate to express his opinion that those who oppose the use of the International Rules are acting selfishly and against the interests of the science which they pretend to serve.

I feel these things very deeply. In common with many other systematists, I have spent a considerable amount of time during five or more years to reduce the described genera of my favorite group to a definite basis. In view of some correspondence which has reached me recently and has brought my interest in the matter up to its present pitch, I cannot but feel that such efforts are, at least for the present, wasted. These genera have never been consistently worked over. It would be relatively simple to fix the type of each by the International Rules, but what would be gained if Richard Roe should insist that he could not accept certain results, and John Doe that certain others are against his beliefs? The result does not hinder their work, for in order to object intelligently they must understand all phases of the points involved. The greatest difficulty accrues to those who are not students of nomenclature, perhaps even indifferent systematists. In other words, by insisting upon points of personal opinion in matters which are not vital, the systematist hinders him whom he

would help, to whom a real and conclusive stabilization of nomenclature would be invaluable.

We have the International Rules. They are clear and applicable, and with the settlement of European difficulties it should be possible to arbitrate properly the few doubtful points which may arise. Why should not every systematist suppress his personal desires, accept the few changes which result from the use of the rules, and establish for all time this important, but none the less accessory, framework of science?

NOTE: This paper was written in the winter of 1921-22, revised and placed essentially in its present form in the Fall of 1922, and brought out again in the early Spring of 1924. On the eve of its publication the writer's attention was caught by an article by Professor E. B. Babcock,[28] a botanist, in which reference was made to Hall and Clements' "Phylogenetic Method in Taxonomy,"[29] The striking degree of agreement between the views expressed in the latter paper and in the preceding pages, where they touch upon the same subjects, is such as to compel its mention here. It seems that both botanists and zoologists are agreed upon the requirements of this branch of science, and we may hope that the future will extend the valuable renovation of methods which the present has begun.

[28] Babcock, E. B., Genetics and Plant Taxonomy, Science LIX, 327, 1924.
[29] Hall, H. M. and Clements, F. E., The Phylogenetic Method in Taxonomy, Carnegie Inst. of Washington, Publication No. 326, 1923.

NOTES ON THE GEOLOGY OF GILES COUNTY, VIRGINIA

By *GEORGE D. HUBBARD and †CAREY G. CRONEIS

INTRODUCTION

Location and Extent of Area

Giles County is in the northern section of the southwestern portion of the State of Virginia. It is bounded on the north by the State of West Virginia, on the east by Craig County, on the south by Montgomery and Pulaski counties, and on the west by Bland County. Pearisburg, the county seat, which lies a little north and west of the geographical center, is 37°19′N latitude and 80°44′W longitude.

Inclosed within the irregular boundaries of the county are a trifle less than 350 square miles.

Previous Work

In 1881, Boyd[1] published his "Resources of Southwest Virginia," which contained, among other things, a short account of the geology of Giles County. Boyd, however, had merely summarized the also short account which appeared in W. B. Roger's "Geology of the Virginias" in 1841. The work, excellent for having been done in the early forties, was not so good forty years later. Boyd also gives a rather complete account of the county's mineral resources. Here it may be said that Mr. Boyd was an optimist when he was discussing the iron ores of Giles County. However, it should be added that he was also something of a prophet when he was discussing manganese prospects. Of this more will be said in the chapter on Economic Resources.

Stevenson,[2] in 1887, made a geological reconnaissance of a half a dozen counties in the southwest portion of Virginia. Giles was one of the counties visited and Stevenson's observations on

* Department of Geology, Oberlin College.
† Department of Geology, University of Arkansas.

[1] Boyd, C. R., "Resources of Southwest Virginia," J. Wiley & Sons, 1881.

[2] Stevenson, J. J., "A Geological Reconnaissance of Bland, Giles, Wythe and portions of Pulaski and Montgomery Counties of Virginia." Proc. of Amer. Phil. Soc., Vol. 24, 1887.

it were very good, considering the short time spent in the area. To quote the author, "The examination of the area under consideration was purely a reconnaissance, and the notes in several localities must be regarded as little more than suggestions to the one who may make the detailed study on behalf of the U. S. G. S." Stevenson, who was at the time Professor of Geology at the College of the City of New York, was a keen observer, and his work is not without value even today. A geological map accompanying the report, while recognizing but few divisions, is fairly accurate over wide areas.

In addition to the above mentioned work, the U. S. G. S. in 1884-7 made a reconnaissance map of the Dublin, Virginia-West Virginia quadrangle, in which is contained the greater part of Giles County. On this map, elevations are found to be very good, but no depression contour appears on the Dublin sheet, although there are many sinks in the county whose depth is close to 150 feet. However, everything considered, this topographic map is extraordinarily good for reconnaissance work. It was used, with corrections and modernization, as the base for the geologic map accompanying this report.

In 1907, Watson[3] published his "Mineral Resources of Virginia," which mentions the iron mines of the county, as well as the possibilities for the manufacture of cement.

Two years later, in 1909, there appeared Bassler's[4] "Cement Resources of Virginia." In this volume the stratigraphy of southwest Virginia is worked out in some detail. Giles County receives its share of attention, but post-Ordovician formations here, as elsewhere in the work, are slighted since they are not potential cement horizons. However, the writers have found this bulletin to be the very best of any of the meager sources of information on the Geology of Giles County.

Stose and Miser,[5] in their bulletin on the "Manganese Deposits of Western Virginia," which was published in 1922, give a complete account of the prospects in the county under discussion. Physiographic forms, stratigraphy, and geography of western

[3] Watson, T. L., "Mineral Resources of Virginia," Jamestown Exposition Commission, 1907.

[4] Bassler, R. S., "Cement Resources of Virginia," Bulletin 2A of the Virginia Geol. Survey, 1909.

[5] Stose, G. W. and Miser, H. D., "Manganese Deposits of Western Virginia," Bulletin 23 of the Virginia Geol. Survey, 1922.

Virginia are also discussed briefly in this bulletin, which has been used rather freely by the writers.

The above list completes the published references to the geology of Giles County. In addition, however, Watson has published a geological map of the state of Virginia. The geology of Giles County, on this map, is simply represented by five large divisions, whose boundaries are not extremely accurate.

METHOD OF WORK AND ACKNOWLEDGMENTS

Field parties of students gathered from various colleges and universities have for some time worked in this region as a part of the Oberlin College Summer Session. The work was started in 1908 in Bland County and since that date nine other parties have studied in the region, and eight of these in Giles County itself. The camp from which the work was done has been each year in a new place so that a considerable part of the county has now been worked. Over 75 students have contributed to the solution of the geologic problems of the area. During each of these years a portion of the geologic section has been measured and described in detail, and this description has been handed on to the next class, so that a considerable heritage has accumulated.

In like manner collections of rocks and fossils have been made and added to the collections of former classes. Lists of characteristic fossils have thus been built up for several formations and for a larger number of members. No publications have ever come from this work but there is now a large body of data available for detailed study. It is hoped to put this material into shape for publication as special papers or topical studies, but first there seemed to be need for a general paper covering some such unit area as a county. Hence this paper has been prepared.

The sections recorded in the body of this paper are the accumulations of the several summers of work. Only a small percent was actually measured and described in any one year. Credit is due each class for its contribution to the whole. Credit should also be given Messrs. E. R. Smith of De Pauw University and C. W. Honess of Oklahoma University for special work on the fossils. They have spent a second summer collecting and have given much time to the study and identification of the various forms collected.

TOPOGRAPHY

Physiographic Location

The State of Virginia is divided into three physiographic provinces,* which are named, from east to west, the Coastal Plain, the Piedmont Plateau, and the Appalachian Mountain divisions. The last named province is again divided into the Blue Ridge, Great Valley, and Alleghany Ridge regions. Giles County is included in the last named, or westernmost, of these divisions. The irregular valleys and ridges of Flat Top Mountain area are, however, more characteristic of the Cumberland Plateau region than of the Alleghany subdivision. On the other hand, East River, Wolf Creek, Sugar Run, Little and Big Walker mountains are typical zigzag or parallel eminences of the true Alleghany Ridges, defended by a strong sandstone.

Peters and East River mountains are the first westernmost ridges and mark the initial sharp upturning of the strata. To the northwest from these ranges is the much dissected, mature Alleghany Plateau region whose strata are nearly horizontal or very slightly flexed, but contain no true folds. However, a little south of the point where the New River enters West Virginia, the pronounced folding begins and, in a short distance, indeed in one formation (the Hinton), the dip increases from the horizontal to past the vertical.

Relief and Drainage

The central portion of Giles County is a broad lowland, wherein flows New River, the master stream of the area. The western portion of the county is made up of irregular ridges and intermontane valleys. The eastern portion is much the same, except for the fact that the mountains here are consistently some 500 feet higher than those on the west. On the north, except where

* Hayes, C. W., The Southern Appalachians. Nat. Geog. Mon. 1895, pp. 305-36.
Willis, Bailey, The Northern Appalachians. Nat. Geog. Mon. 1895, pp. 169-202.
Hayes, C. W. and Campbell, M. R., Geomorphology of S. Appalachians. Nat. Geog. Mon. 1894. pp. 63-126.
Bascom, F., Cycles of Erosion in Piedmont Province of Pennsylvania. Jour. Geol. vol. 29, pp. 540-559.
Campbell, R., Clapp, F. G. and Butts, Chas. U. S. G. S. Folio 189.
Shaw, E. W., Bull. G. S. A. vol. 28. p. 128.

the small projection of Giles County extends into West Virginia, there is a natural boundary in the East River—Peters Mountain range, which is a somewhat uniform ridge approximately 3500 feet in height.

The southern boundary is, in the same manner, defined by a ridge running parallel to the mountains described above. This is the Walker-Gap Mountain range which is from 500 to 1000 feet lower than the East River—Peters range. A distance of 12 miles, on the average, separates the two ridges.

The highest point in the County is Bald Knob, in the east-central mountain region, whose elevation is 4,348 feet. The point where New River enters West Virginia has, of course, the minimum height, which is 1472 feet. Giles County, then, presents a maximum relief of 2876 feet.

Johns Creek, a tributary of the James River, has its source on the upper eastern slopes of Salt Pond Mountain. The extreme eastern portion of the county, then, drains into the Atlantic by way of James River. The divide between the streams flowing to the Atlantic and those tributary to the Mississippi system, may be drawn in Giles County along the crest of Salt Pond and Johns Creek mountains. This entire basin, however, does not comprise more than eight square miles so that, for practical purposes, it might be said that the county was drained by New River and its tributaries.

New River rises near Blowing Rock, N. C., and flows northeast to Radford, Virginia, a distance of about 100 miles. Here, it turns to the northwest and cuts through the mountains of Virginia and West Virginia to join the Ohio at Point Pleasant where it is called the Kanawha (as it is throughout its lower course). This system is, of course, antecedent to the uplifts and crustal movements which developed the Peters and Walker mountains. In fact, New River is the only one which has, in the Appalachians, preserved its Cretaceous or pre-Cretaceous course to the westward. This has been due, in large part at least, to differential warping which raised the headwaters so high that enough gradient was developed to enable the river to cut through the hard sandstones of the Walker and Peters ridges. These were elevated with the rest of the region, but slowly enough so that the river could maintain its course in spite of the elevation.

From Angels Rest, or Bald Knob, New River Valley looks

much like a great amphitheatre, which is walled in at all sides except where the stream enters and leaves the county. The entrance is by way of a narrow valley which is cut across the Walker-Gap Mountain ridge. The exit is by a similar valley, even more restricted, cut in the East River-Peters Mountain system. The principal tributaries to the New in Giles County are Walker, Wolf, and Sinking creeks. All of these streams, however, have their sources outside the county. East River, which has its headwaters in Virginia, flows, through most of its course, in West Virginia only to enter the New by way of Giles County. However, since it flows less than a mile in the County, the portion it drains is neglible.

The relative absence of small tributaries is a feature which is apparent at once. Streams which are carrying considerable water in their upper valleys are much restricted in size, when they enter the limestone area adjacent to the New River. This is due to the large amount of drainage which is under ground in Giles County, and of which more will be said later.

Erosion Cycles

In Giles County, the elevation of the highest peneplain cannot be determined accurately because, having suffered the most from erosion, few of its remnants remain. In spite of this fact, Doe Mountain, Pearis Mountain, Angels Rest, and portions of the crest line of Peters and East River mountains have a fairly uniform height of 3500 feet. This elevation represents a former peneplain surface, which probably was completed in late Jurassic time. In this paper, this peneplain will be referred to as the Pearis Peneplain.† Above this early plain, which was then close to sea level there rose monadnocks to the height of 200 to 800 feet. Today Bald Knob, Butt Mountain, and portions of Sugar Run Mountain remain as remnants of these former elevations.

† Correlation in this paper is with Stose and Miser, who have given us one of the latest interpretations. It should be borne in mind that they assign earlier dates to most of the erosion plains than do Willis, Campbell and others; and also that Shaw has ascribed later dates than the older workers. In order to determine the dates of these peneplains it is necessary to trace them eastward and southward where they disappear under sediments of the Coastal Plain. Our work has never allowed us to carry forward such tracing hence we probably should not commit ourselves at all, and thus our correlations with the work of others in the Valley of Virginia and with Willis in the Northern Appalachians must be looked upon as provisional.

Brushy and Spruce Run mountains, as well as portions of Walker, Peters and Flat Top mountains have a height of approximately 3100 feet. This is the probable elevation representing a second base level which was only partially completed in Cretaceous time. This old base level will be referred to as the Spruce Run Peneplain.

A third and still less extensive base level was partially reached in early Tertiary time (probably late Eocene). This old surface is represented by heights in Buckeye Mountain, and by numerous spurs on all the mountains having the uniform height of about 2500 feet. This base level will be called the "Buckeye Peneplain" in this report.

A fourth, and last base level, which was in all probability reached in late Tertiary time, is represented by the numerous elevations in Giles County of approximately 2100 feet. This valley floor peneplain will be referred to as the "Pearisburg" base level. Remnants of this old surface are better developed in Monroe County to the north than they are in Giles, however, much of the land about Pearisburg and at various points along New River stand at this elevation. On this level are quantities of gravel, sands and clays of fluviatile origin.

In latest Tertiary and in Quaternary time, New River has cut its present gorge in this area. Work towards the ultimate base level has scarce begun, yet the valley has been incised at least 400 feet. In the future, lateral planation will exceed vertical cutting in this county, because the New River is regulated by the natural quartzite dam across its valley at the Narrows. This resistant rock can be cut only very slowly, so that above the Narrows the limestone valley probably will continue to broaden rather rapidly.

The peneplain surfaces in Giles County are not so well defined as they might be, yet it is possible to make a rough correlation of the base levels recognized here with those described by Stose and Miser[6] as occurring in the Valley of Virginia.

The Upper peneplain at 3500 feet is undoubtedly the same as the Summit Peneplain of Stose and Miser, at an elevation of 3000-3800 feet. This base level is regarded as older than the Kittatinny peneplain of Pennsylvania. The Spruce Run pene-

[6] Stose, G. W., and Miser, H. D., Va. Geol. Surv. Bull. 23. "Manganese Deposits of Western Virginia," 1922. pp. 20-22.

plain corresponds roughly to the Upland peneplain of Stose and the Kittatinny peneplain. The elevations grade from 3100 feet in Virginia to less than 2000 feet in Pennsylvania. The Intermediate peneplain, as described by Stose, is in Giles County developed as the Buckeye Peneplain, which here is some 250 feet higher than farther east. The Valley-floor base level of Stose, is the Pearisburg Peneplain of Giles County. Here it is 100-200 feet higher than it is to the east in the Valley of Virginia.

Since Jurassic time it is evident that Giles County has been elevated some 3000 feet. The most widespread peneplain was the first. The later ones were successively smaller and more incomplete. The present drainage is about 1500 feet above sea level. A peneplain this far from the sea would probably stand 300-400 feet above sea level.

Underground Drainage

A very prominent feature of this area is the sink hole topography. As has been mentioned before, the U. S. G. S. map of 1884 does not indicate any depression contours. However, these sinks develop with considerable rapidity, some of the older natives recalling a half a dozen of ordinary size which have appeared during their life time. The writers do not from this intend to convey the idea that the sinks were too small to be mapped in 1884. Their omission from maps of this issue is regarded as the result of the reconnaissance nature of the mapping, or to the fact that, at that date, no depression contours were used on any maps.

Sinks are confined to the limestone areas of Giles County. So common are they, that they can be of use in determining the outcrop of the Shenandoah and Chickamauga formations, to which horizons they are limited. Caves are invariably found at the bottom of the sinks. The latter have been formed by the falling in of the roofs of solution passages, which ordinarily have formed along joint plains. Some of the caves are so extensive that it is possible to travel many hundreds of yards through their various passages.

In many cases, the surface drainage is in the reverse direction of the underground, so that when an entire series of sinks develop along prolonged joint planes (as they often do), the surface drainage is reversed. As a result of this underground

type of drainage, many great springs are found bordering the New River, and small tributaries are uncommon in the limestone areas. The New, itself, seems to vary greatly in size over small areas. The writers believe that this is due to the fact that, some of its water, at places, flows underground or in crevices for a distance, only to join the surface waters of New River again in the form of great springs, some of which may be hidden but many of which are visible. Of course solution topography and underground waterways could not be developed much below the water table.

No typical karst topography has developed in Giles County, but the sink hole areas are usually turned into grazing lands since the soil mantle is too thin to be easily cultivated.

STRATIGRAPHIC GEOLOGY

INTRODUCTION

In Professor W. B. Rogers' classification of the geological formations appearing west of the Blue Ridge in Virginia, fourteen groups of strata were given numbers, beginning with the oldest. His brother, Professor H. D. Rogers, divided the Paleozoic rocks of Pennsylvania into fifteen sets, "extending from the deposits which witnessed the very dawn of life upon the globe, to those which saw the close of the long American Paleozoic day." Thus the names of these formations were the various parts of the day, instead of the ordinary geographic terms used. Extremes, then, of his classification were Primal, signifying the dawn (that is, lower Cambrian), and Seral, meaning night (and corresponding to the coal-measures.) In the literature of Virginia, both systems have been used. A table is introduced here to show the relation between these classifications and the one now in use.

The rocks of Giles County comprise all of the divisions of the Paleozoic from lower Cambrian to the lower Carboniferous inclusive. No younger consolidated strata are found, but some Tertiary gravels are present, which may be the approximate equivalent of the so called "Orange Sand" found in the states further west. Limestones are quantitatively in predominance in Giles County, being especially well developed in the older Paleozoic divisions. Besides limestones, there are shales, cherts,

CORRELATION TABLE OF GEOLOGIC FORMATIONS OF WESTERN VIRGINIA

Era.	Period.	Virginia and Pennsylvania Report Numbers.	First Pennsylvania Report Names.
Paleozoic	Pennsylvanian	XIV, XIII, XII	Seral.
	Mississippian: Upper	XI	Umbral
	Mississippian: Lower	X	Vespertine
	Devonian: Upper	IX	Ponent
	Devonian: Upper	VIII	Vergent, Cadent
	Devonian: Middle	VII	Post-Meridian, Meridian
	Devonian: Lower	VI	Pre-Meridian
	Silurian: Upper	V	Scalent
	Silurian: Middle	V	Surgent
	Silurian: Lower	IV	Levant
	Ordovician: Upper	III	Matinal
	Ordovician: Middle	III	Matinal
	Ordovician: Lower	II	Auroral
	Cambrian: Upper	II	Auroral
	Cambrian: Middle	II	Auroral
	Cambrian: Lower	I	Primal

conglomerates, breccias and sandstones. The latter are sometimes metamorphosed partially into semi-quartzitic divisions.

Most of the ridges are capped by the Clinch sandstone, which is a very resistant division of the Silurian, while the valley floor is usually the Shenandoah Limestone. Outcrops are often decreased or made wider by the complex folding and faulting.

On the following page is a table of the formations found in Giles County.

THE CAMBRIAN SYSTEM

Introduction

The Cambrian of Giles County is made up of limestones and shales in the lowest division, and of limestone and dolomite in the upper portions. The Middle Cambrian time seems to have been one of erosion in this area, although the unconformity between the Lower Cambrian Russell and the Upper Cambrian Shenandoah is not marked. Deposition was continuous from Upper Cambrian on into Ordovician time, hence the great Cambro-Ordovician limestone series.

The Russell Formation

The Russell Formation, composed of variegated shales, massive and impure limestones, takes its name from Russell County, Virginia, where it is found developed to its fullest extent. It is probably equivalent to Apison and Rome formations of Southern Tennessee.

In the Pearisburg section, it is brought in over a small area running with slight variation east and west through Bane, by the large anticline between Pearis and Walker mountains. In this exposure, it is non-fossiliferous but in some localities* it carries the Olenellus fauna of Lower Cambrian time. The formation passes from medium bedded, resistant, blue gray, blotched, limestone at the base, through highly colored green and chocolate shales and intermediate limestone lenses and layers, to greenish and yellow shales, which, in some places, grade directly over into the Shenandoah formation but in other places are separated from it by several feet of white and gray calcareous shales.

Four small anticlines, the largest of which is approximately

* Russell County, Virginia.

NAMES OF FORMATIONS

Period	Names used in this Report	Rogers[1]		Stevenson[2]
MISSISSIPPIAN	Hinton formation	Greenbrier shale	XI	Umbral shale
	Bluefield shale		XI	
	Greenbrier limestone	Greenbrier limestone	XI	Umbral limestone
	Pulaski shale	Not described		Not described
	Price sandstone	Montgomery grits	X	Vespertine
DEVONIAN	Kimberling shale	Catskill	IX	
		Chemung	VIII	Chemung
		Portage	VIII	
		Genessee	VIII	
	Romney shale	Hamilton	VIII	Hamilton
		Marcellus	VIII	
	Giles formation	Oriskany	VII	Oriskany
		Lower Helderberg	VI	Lower Helderberg
SILURIAN	Rockwood formation	Clinton	V	Clinton
	Clinch sandstone	Medina	IV	Upper Medina
ORDOVICIAN	Bays sandstone	Medina	IV	Lower Medina
	Sevier shale	Hudson River	III	Hudson
	Moccasin limestone	Utica	III	Hudson
	Chickamauga limestone	Trenton	III	Trenton limestone
CAMBRIAN	Shenandoah limestone	Chazy	II	
		Levis	II	Knox limestone
		Calciferous	II	
	Russell formation	Not described	?	Knox shale

[1] "The Geology of the Virginias, 1884."

[2] "A Geological Reconnaissance of Bland, Giles, Wyth, and Portions of Pulaski and Montgomery Counties, 1887."

1000 feet across, and numerous structures of a few feet each, mark the crest of the larger anticline and make measurements to determine the thickness of the Russell Formation highly unsatisfactory. The thickness, however, cannot be less than 300 nor more than 400 feet.

The formation clearly marks a transition period which may have introduced the time of erosion correlated with the lack of Middle Cambrian, and directly preceding the time of deeper seas prevalent during the formation of the Shenandoah Limestone. That the formation is a weak one is clearly shown by the numerous folds throughout the entire thickness, some of which do not appear at all in the adjacent Shenandoah. It disintigrates rapidly into a soil which is not as fertile as that resulting from the decomposition of the Chickamauga and Shenandoah Formations.

The Russell Formation Subdivided[7]

x. At the base of the Russell formation is a medium even-bedded limestone exposed along Walker Creek below Bane. It resembles the Shenandoah in some of its characteristics and is very different from the usual Russell. It runs under the typical Russell and is obviously older, but since its base is not exposed it may be a lens with more typical Russell underneath. For this reason this division is here called x and grouped under the heading of Russell. The color is blue to gray with red and purple lines and blotches which give the member a purple tinge. It is very hard and resistant because it is in part siliceous. Very fine crystalline to dense with weak irregular jointing. There are many branching calcite veins which are thin and thread-like in appearance. No chert nor fossils seen. Weathers dirty blue and black, rarely light blue. In the stream the red lines and blotches are emphasized by weathering so that the entire rock appears red. It is a ripple maker in the stream.

Thickness 80-100 feet +

1. CHOCOLATE, GREEN, AND BLUE SHALES

Medium to thick bedded shales with prominent cross-bedding and jointing in all directions. There are a few master joints. There are also sandstone and limestone lenses, the latter of which are dense blue layers six inches to two feet in thickness and

[7] In all the subdivisions, the numbering is from the bottom up.

many feet in breadth. The colors grade into each other both vertically and horizontally. Great blotches of green or red are common. Weathers rusty brown to black. No fossils were seen.

About 150 feet.

2. CALCAREOUS SHALES AND LIMESTONES
(THE MIDDLE LIME)

This division is thin bedded for the most part but there is one layer about eighteen inches in thickness. In general, the colors are buff to blue in the limestones, and green to brown in the shales, the entire formation weathering a dark brown, except a light blue 4 inch limestone layer which becomes yellow to white. In some places, it is paper bedded; blue with delicate yellow layers alternating. There are calcite veins, and in a limestone lense-like layer, there are cavities partially filled with calcite crystals.

From 10 to 30 feet.

3. GREEN AND YELLOW SHALES

Calcareous to sandy, thin, red layers occur. The formation is thin bedded, and rather regularly jointed so as to break into blocks. Weathers yellow and brown and disintegrates more rapidly than division number one.

About 50 feet.

4. BLACK AND GRAY SHALES

These occur locally below the Shenandoah and probably belong to the Russell formation. The colors are black, gray to nearly white, weathering a dirty black to mud color. These shales are dry, fissile and non-fossiliferous. They may be erosion remnants.

Thickness 0-10 feet.

Besides the exposure at Bane, the Russell outcrops about a half mile farther down Walker Creek and is also exposed over a very limited area at the Norfolk and Western Railroad cut near Goodwins Ferry. (Not shown on the map)

Bassler[8] believes that the formation has a thickness of at least a thousand feet in the vicinity of Clinchport, Virginia. He says, "Although the major portion of the formation is of little value from an economic standpoint, the argillaceous shales of the upper division may prove of use for mixture with pure limestones in

[8] Bassler, R. S. "Cement Resources of Virginia", pp. 148.

the manufacture of cement." However, the great range in the composition of these shales as indicated by the following analysis, should lessen the possibilities in this respect.

ANALYSIS OF THE RUSSELL SHALES

Vicinity of Clinchport

(J. H. Gibboney, Analyst)

	1	2
Insoluble	41.72	89.52
Alumina and iron oxide	5.68	7.22
Lime	17.32	0.42
Calcium carbonate	30.93	0.72
Magnesia	9.17	1.05
Magnesium carbonate	19.29	2.21

While these analyses were made from samples of the Russell formation from a different area than the one under consideration, they may serve to give some conception of the composition of these shales in Giles County.

This is the first time that the Russell has been reported from Giles County, the reason being that the formation weathers so rapidly that it quickly covers itself up. The exposures noted above were first found in recent road or railroad cuts.

CAMBRO-ORDOVICIAN

The Shenandoah Limestone

The Shenandoah Limestone is a heavy bedded, gray blue, dolomitic, limestone near the top, grading downwards into a darker more sandy limestone at its base. It takes its name from the Shenandoah Valley where it outcrops very extensively. There is a breccia at its base in some places whose fragments are made up of bits of shales from the older Russell formation. In other localities, this formation has been subdivided into or corresponds with the Honaker Formation, the Knox Dolomite, and the Nolichucky Shales. It probably corresponds, except for the upper portions, with the Beckett Gneiss of New England, the Potsdam Sandstone in New York, and the Stissing Slates, all of the Upper Cambrian. However, Beekmantown, and even Trenton fossils are occasionally found in the uppermost layers.

This limestone has a thickness of at least 5000 feet at places

and includes many shale and sandy lenses and partings. It is for the most part rather heavy bedded and dense, but includes such wide variations in its great thickness that it is hard to generalize. It carries a large amount of chert in lenses and in nodules, the chert being both light and black, but the light is in great preponderance and the black occurs only in the lower layers.

The formation is for the most part calcite veined, with calcite nodules and calcite-filled cavities numerous. Pyrite occurs in the shape of pyritohedrons, and limonite and hematite pseudomorphs after these crystals are not uncommon. Fossils are uncommon in the limestone but a few gastropods occur as well as other fossils too fragmentary to be recognized. However, in some places the chert is quite fossiliferous and gastropods, brachiopods, and sponges can be identified.

The rock usually weathers light and has an uneven to conchoidal fracture. Many layers are wave marked. The jointing is as a rule not pronounced; however, it is so good in the county road cut along Walker Creek between Bane and Staffordsville, that the joint planes are with difficulty distinguished from the bedding planes. Practically all the valley floors are made up of Shenandoah Limestone, and the white chert remaining after the limestone has disintegrated is found widely scattered.

The limestone is quarried in several places in this region and is used extensively for ballasting, for lime making and for building purposes. The soil resulting from its disintegration is rich and productive.

The Shenandoah Subdivided

Section along the Virginian Railroad cut at the Narrows of the New River

1. Gray blue, fine grained, rather massive limestone, with shale partings of one to three inches. Flattened layers of black chert and a few small calcite veins. The limestone layers are from several inches to three feet in thickness. The formation weathers light buff to white, losing all the blue. The fracture is uneven to conchoidal with minor jointing vertical to the bedding planes. No fossils seen. Dolomitic. 25 feet.

2. A gray blue, fine grained, massive limestone with no chert, having, however, nodules and veins of calcite arranged in all

directions. The layers are two to six feet in thickness. About six feet from the base, there is a two foot layer which is considerably darker than the rest of the division. Weathers light buff to white but does not bring out the bedding. The fracture is conchoidal with coarse patterns. Joints are rare and small. No fossils seen. Dolomitic. 20 feet.

3. Color as in one and two—fine grained, crackled and hackly, siliceous limestone of 11 feet between a one foot layer of light cherty limestone at the base and a blue cherty layer of two feet at the top. Weathers black to buff. No fossils seen. No calcite veins and no chert in the middle portion. 14 feet.

4. Gray crystalline limestone layer with no apparent bedding. No chert. Joints intersect in all directions giving angular blocks of small size. Calcite nodules numerous and a little calcite along the joints. Weathers dark. No fossils seen. 10 feet.

5. Light siliceous limestone with veins and small nodules of calcite, also of quartz, and the entire division is sprinkled with quartz grains. This division is conspicuous as a light band across the face of the cliff as it weathers very light. There are disconnected delicate pink threads shot throughout the layer. 3 feet.

6. Dove colored, fine grained, dense, siliceous limestone with inconspicuous bedding. No chert, but with numerous calcite veins, some of which are in the joint planes. Calcite nodules and crystals give this division a mottled appearance. No fossils seen. 7 feet.

7. Bluish, massive, cherty, crystalline limestone, with round quartz veins and fragments of chert and chalcedony. The bedding is not apparent. Weathers brownish with ferruginous blotches. Crystals of light and dark calcite give a pronounced mottled appearance to some layers. Coarse, hackly fracture and little jointing; no fossils. 31 feet.

8. Bluish gray to drab, dense, fine grained, crystalline, uneven bedded limestone with calcite veins and bunches of calcite crystals. Fractures and weathers as No. 7. Joints are rare but when they do occur they are in all directions. This division seems to be a leveling up layer on a surface of marine erosion. 4 to 8 feet.

9. Medium to coarse crystalline limestone, light gray in color. Distinct layers of light chert are numerous towards the bottom.

Some of this chert is translucent. Minor joints at various angles developed by weathering. Calcite veins are numerous and minute and form a network through the member, which weathers red and brown. 24 feet.

10. Similar to No. 9 but darker, thinner bedded, and more coarsely crystalline. Wave marks are pronounced about two feet and a half from the top. 9 feet.

Note: Small faults of 10 inches and 2 feet respectively below and above No. 10. Numbers 9 and 10 constitute a rather mashed zone.

11. Dove colored and pink mottled limestone, much jointed into small cuboidal pieces. Fine grained, felsitic with no chert. Inconspicuous veins of hematite and limonite. 2 feet.

12. Gray blue, massive, dense, fine crystalline limestone, coarser towards the top. One heavy layer. Many heavy calcite veins some as thick as a half an inch, at right angles to the bedding planes. Traces of pink common in the lower parts. 6 feet.

13. One foot layer of coarsely crystalline limestone, greyish blue in color. 1 foot.

14. Blue gray, fine crystalline limestone, which is rather heavy bedded. There are three zones of chert nodules located respectively at the top, middle, and base. The chert is both light and dark. Calcite crystals occur in veins and in bunches. The bedding is not distinct but there are many irregular joints. Weathers a dirty brown. No fossils seen. 25 feet.

15. Bluish limestone in layers of two feet each, fine grained and dense at the bottom, with coarse crystalline layer, ill defined and of uneven thickness at the top. Calcite veins minute. Darker than most of the units; has siliceous black shale layers in which are embedded fragments of a very different limestone. These shales vary in thickness from a knife edge to five or six inches and are crumpled in many places. Wave marks at the top. No chert. Former small cavities in limestone are filled with calcite crystals. 11 feet.

16. Single layer of light bluish limestone with conchoidal fracture. No chert but much calcite veining, often more than a half inch in thickness. Mostly fine grained, but with pieces of coarse crystalline limestone and sandstone embedded in the layer. 6½ feet.

17. Dark gray crystalline limestone, rather massive but with bedding concealed. Many crooked joints running in all directions developed by weathering. The lower six feet are coarser crystalline than the rest, with threads and knots of chert throughout, calcite veins and bunches of crystals all through the member but increasing towards the top, where a mottled appearance is developed. Some small shale lenses. Pyrite is present in cubes and pyritohedrons, and there are pseudomorphs of limonite and hematite after these crystals. Weathers dark to black with chert and calcite in relief. 20 feet.

18. Color the same as in 17, but lower part has red streaks and spots. A dense, finely crystalline, felsitic appearing limestone in beds up to three feet in thickness. Several layers of light colored chert lenses and nodules occur. Calcite veins in places, with jointing rare and irregular. Weathers a rusty brown, not black. Bryozoans at the base. 11 feet.

19. Limestone, a dove color below to red above with calcite veins white to green and crystal lined cavities. Bedding is not distinct. Upper part becomes crystalline and slightly arenaceous. Veins are often not completely filled. Joints are irregular. No chert. Weathers brown. 4½ feet.

20. Thin red shale, thicker limestone, thicker red shale, and six feet of sandy and shaly, red limestone constitute this unit. It is capped by a few inches of shaly sandstone, which has reddish and greenish streaks. No layers are constant, the shale is fissile and ferruginous with inclusions of limestones. There is a layer of chert nodules in the upper limestone. 9 feet.

21. Dark blue, compact, fine grained, even layered limestone, mottled with light blotches of chert and calcite crystals. Joints are very rare but the formation breaks into even blocks to make good building stone. Weathers lighter but into a dirty brown. 3 feet.

22. Dark, red and green streaked, cross bedded sandstone, in two or three layers. White quartz in knots and crystals. There are also crystals of calcite and pyrite and chert nodules. 1 foot.

23. Dark blue limestone layers of three inches to three feet, which is darker above. Weathers a dirty gray to buff. The upper part has cavities lined with calcite and the entire unit has quartz

lined cavities. There are red blotches on the surface due to oxidized iron. 10 feet.

24. Interbedded black and white chert and shale layers, with one irregular limestone layer about four inches in thickness. The bedding is more distinct towards the bottom where jointing becomes abundant. There are several waved surfaces. Calcite veins and nodules with large pseudomorphs of limonite. 5 feet.

25. Several grayish, dense, limestone layers of less than two feet each in thickness. The upper layers, on weathering, bring out the thin bedding. There are also thin partings of light, calcareous shale. Joints are rare and irregular. Red blotches and threads, with little calcite and no chert. Fossils seen about half way up the unit. Limonite pseudomorphs. 11 feet.

26. Blue, heavy bedded, medium crystalline limestone with definite layers and chert nodules. Some layers are siliceous but not sandy; the main beds, six in number, show minor beds on weathering. There are several small shale partings and one ferruginous, flinty parting which is cross-bedded. There is also a one foot calcareous, shale layer seven feet from the top. 47 feet.

27. A faulted zone with slickensides common. Most definite fault is the southern and has a dip of fault plane about 67°N 89° W. Strike is therefore N 1° E. Two or more major faults occur to the north of first one but the dip and strike and amount of displacement are not determinable. This is a brecciated zone of greatly smashed and distorted strata. Probably 103 feet.

28. (We are now on the wagon road, having been on the railroad up to this point). Heavy bedded, bluish grey, finely crystalline limestone with layers and nodules of white and light blue chert, some layers of which are 2 inches thick and single nodules 6 inches across. There is little jointing but there are calcite bunches. The top of the unit is wave marked with crests three feet apart, with a shaly parting at the surface. Weathers red and rusty. 27 feet.

Wave markings and shale partings may mark change in conditions and life, but there seems to be no change in dip or strike and little change in the lithological phase of the rocks. The wave marks and crests trend N 15 to 20 degrees E.

29. Grayish blue limestone layers above shale parting two inches to three feet in thickness. Joints are vertical but not at right angles to the bedding. Other joints give sharp angles. There are calcite veins and a little chert. There are several shale partings with cross bedding in the lower layers, but the third layer is leveled up. Lower layers have conchoidal fracture. Rock is fine grained to fine crystalline. Weathers to bring out the bedding. 34 feet.

30. Group of gray to brownish thin layers of quartzitic sandstone, with shale below. 2 to 4 inches.

21. Blue to blue gray, fine grained siliceous limestone, with much black and grey chert. One layer of the chert toward the top is nearly continuous. The unit has a hackly fracture with little jointing. Many calcite veins weather in relief. Weathers buff, brown and black. 3½ feet.

32. Felsitic to fine crystalline massive, bluish, limestone becoming lighter above. Bedding is not clear but is developed by weathering in the upper portion. In crystalline layers the calcite weathers out and feels like sand on the surface. Calcite veins weather in. Much black chert in layers of nodules. Jointing is rare. Top layer seems to be wave marked as well as others and there are some thin shale partings on the wave marked surfaces. Weathers a reddish brown to nearly black. 24 feet.

33. Several limestone layers similar to 32 but thinner bedded, capped by a thin bed of bluish to reddish shale a few inches in thickness. In some places the shale contains chert and limestone pebbles as if residual. 11 feet.

34. Series of broken limestone beds similar to 33 with three small faults of a foot or so. Solution work and a filled sink hole are present. The filling is chert, clay and sandstone pebbles. White chalcedonic chert in the lower part. There are two shale partings near the top about a foot apart. 29 feet.

35. Gray, rather massive, uneven bedded, finely crystalline limestone except three feet from the top where it is coarse. There is a pink layer two to four feet from the bottom. There are peculiar pits on the surface about six feet from the bottom. Weathers lighter than the stone to buff, not red. Calcite veins and nodules. Wave marks with a shaly surface at the base. 20 feet.

36. Blue, finely crystalline to felsitic limestone becoming lighter and more felsitic toward the top. Crystals of calcite throughout the entire section. The chert is not noticeable above the first ten feet. In this section, the rock is broken by the growth of concretions, giving a brecciated appearance and contorted beds. There are good dip joints, others are irregular and at various angles. Many of the layers are sandy. Pyrite, limonite, and siderite show on the surface. Weathers dark and differentially, emphasizing the chert in relief, and the calcite along bedding planes in depressions. Beds vary from one to two feet in thickness but there is one single bed of six feet.
53 feet.

37. Dark gray crystalline limestone which is nearly pure in beds which are for the most part four to twelve inches in thickness, but there is one bed of four feet near the bottom. There are bunches of calcite crystals in the thick layer and there are two chert layers, one at the top and the other three feet below. The upper one is of neat rounded concretions with concentric structure. Rock has conchoidal fracture. Weathers buff to brown with large curved surfaces. 12 feet.

Nos. 37 and 38 are found both on wagon and R. R. cuts.

38. Light and dark gray felsitic limestone which looks flinty. Conchoidal fracture. At the middle, there are two layers with pits and knobs which fit together like waffle irons. There is a little black shale along this bedding plane. Chert layers at the base. Weathers dirty buff to brown. 12 feet.

No. 38-44 are all found on Virginian railroad cut.

39. Dark blue, medium bedded crystalline limestone with some calcite veins. There are several shale partings near the top. Red threads occur in the blue limestone. Dip joints are the most pronounced but there are some others present. Near the base there is one arenaceous blue layer. Weathers a dirty brown with the veins weathering in. 25 feet.

40. Lower mottled layer with light and dark gray in bars and blotches. Fine grained and crystalline with calcite bunches showing clearly. The layers are six to twenty-six inches in thickness, with three small shale partings. No conchoidal fracture. Weathers a darker reddish brown. 10 feet.

41. Lower light steel gray layer of fine grained crystalline limestone. Fracture slightly conchoidal. Beds are from 6 to 15

inches. Joints are rare. There are calcite nodules but no veins and no chert. Fossils in a layer of thin black shale one foot below the top of the horizon. Weathers lighter than the rock to yellow. 7 feet.

42. Upper, mottled layer with light and dark grey in lines, bars and blotches. Crystalline and coarse grained more pronounced grains than in the lower mottled layer. There are a few calcite crystals and veins. No chert. Some oblique and irregular joints. One layer only. 2½ feet.

43. Upper, light steel gray layer of limestone. Fine crystalline with conchoidal fracture. The bedding planes are rarely smooth, some being fluted or pitted like waffle irons. Calcite veining in the joints, and there are shale partings between some of the layers. Calcite crystals are common in the upper portion. Two feet from the base there are quartz crystals, iron oxide and an unidentified green mineral. Weathers light. Fossils were found in this member in 1923 consisting of brachiopods, cephalopods, a simple coral one inch in length and the pygidium of a small trilobite. 11 feet.

44. Bluish to dark steel gray, massive but medium bedded limestone whose layers are two inches to three feet thick. It is crystalline and looks like chert but is quite free from it. Joints are rare and the fracture is uneven to conchoidal. Calcite crystals occur in nodules and a few veins. Weathers lighter than the rock to yellow. 4 feet, 5 inches to 10 feet, 8 inches.

Total thickness .....609 feet.

This division does not complete the Shenandoah, but it is as final as can be made in this area. Unit 44 is just below the Chickamauga but unit 1 is an undetermnable distance above the top of the Russell.

THE ORDOVICIAN SYSTEM

Introduction

Ordovician rocks are widely distributed in Giles County, forming parts of the valley floor and sometimes capping lower ridges. The series grades from limestone at the base to sandstone at the top, and shows a distinct graded transition; limesone to argillaceous lime to shale then to arenaceous shale, which grades further into shaly sand and at last becomes a distinct sandstone in the Bays.

The Chickamauga formation has the greatest economic value of any formation in this system. It has enormous possibilities as a cement horizon, can be used for road material or as a building stone. In addition to these values, it distintegrates into a very rich soil. The other formations of the Ordovician have little economic importance.

The Chickamauga Formation

This formation takes its name from Chickamauga Creek in Walker and Catoosa counties, Georgia, where it outcrops extensively. The lower layers are usually composed of a chert breccia which separates it from the Shenandoah, but where the breccia is wanting the separation can be made where the light impure limestone of the Shenandoah is replaced by the blue fossiliferous beds of the Chickamauga.

The breccia mentioned above is in some places 50 feet in thickness and varies from coarse at the base to fine at the top. The breccia consists of chert and non-crystalline limestone fragments in a crystalline limestone matrix. The chert fragments are sometimes as large as 15 inches in their greatest dimension and are always angular and lie in all positions in the matrix. In some localities fragments of sandstone, vein quartz, and quartzite occur along with the chert. This breccia seems to occur in the same horizon as the Birmingham Breccia of Georgia and Alabama, and like that stratum records uplift and erosion somewhere not far distant.

The Chickamauga is usually a blue, flaggy limestone, heavier bedded towards the base. It is sometimes separated from the lower formation with difficulty; however, the base generally carries large quantities of black chert which can be used as a distinguishing feature since the upper Shenandoah contains only light chert. The formation has a hackly fracture and usually weathers blue with water worn rounded forms characteristic. This limestone is more jointed and thinner bedded than the average Shenandoah. The calcite veining is also more prominent in this formation than in the preceding one. The thickness varies from 800 feet on East River Mountain to 700 feet on Big Walker Mountain. At the Virginian Railroad cut at the Narrows 806 feet of Chickamauga is exposed.

The Chickamauga is the great marble producing formation of

the South, but in this locality, while there are a few small occurrences, it is a coarse grained, dull gray rock fit only for building purposes. Like the Shenandoah, this limestone disintegrates into a rich soil, characteristic of such fertile spots as Burke's Garden and the Pearisburg areas. Unlike the underlying formation, however, the undesirable residual mantle of chert is not pronounced. This formation has its greatest development near the margin of the Appalachian Valley.

Paleontology and Correlation

The following is a list* of fossils found in the Chickamauga formation of Giles County:

Tetradium fibratum
Constellaria sp.
Dalmanella fertilis.
Heterorthis clytie.
Dinorthis pectinella
Hebertella clytie?
Girvanella sp.
Solenopora sp.
Eospongia sp.
Agnostus sp.
Malcurea magna
Hormotoma artimesia
Ophileta complanata
Stylarea parva
Echinosphaerites surantium
Isotelus gigas
Illaenus americana?
Rafinesquina sp.
Strophomena sp.
Leptaena rhomboidalis
Orthoceras sp.
Batostoma sp.
Plectambonites pisum

This list seems to indicate that the Chickamauga is early Ordovician in age, as there are forms here which are characteristic of the Beekmantown, Chazy and early Trenton of New York. Almost the same fauna has been described by Ruedemann[9] from a conglomerate inclosed in the Normanskill shales at Rysedorph Hill, Rensselaer County, New York. The conglomerate is made up of pebbles of Beekmantown, Chazy, and early Trenton age. Beekmantown fossils, however, are also found in the upper Shenandoah, but here are also found Cryptozoöns characteristic of the Ozarkian system.

Portions of the above listed fauna are also found in the Stones River, Chambersburg, Murat, Athens, and Holston formations. In the Chickamauga, there is also found resemblance, faunally,

* For the most part, after Bassler and others.

[9] Ruedemann, R., "Trenton Conglomerate of Rysedorph Hill and its Fauna." Bull. 49, New York State Museum, 1908, pp. 1-115.

to the Birdseye (Lowville) limestone of New York and its equivalent, the Tyrone formation of Kentucky. The Hermitage and Bigby formations of Tennessee are also closely related to the upper Chickamauga of Giles County.

The Chickamauga Formation Subdivided

Section along the Narrows of the New River in the Virginian Railroad cut.

1. A coarse chert breccia, with fragments of non-crystalline limestone in a crystalline matrix. The chert fragments are two to fifteen inches in their longest dimension, are angular, and lie in all positions in reference to the bedding plane, often being in contact and sometimes in apparent layers. No calcite veins. 3 to 10 feet.

The chert in the breccia mentioned above is identical with the fragments which weather out of the Shenandoah today.

2. Two layers of fine chert breccia, the fragments being two inches or less in their greatest dimension. Fragments are rarely in contact, nor are they in distinct beds, but are scattered throughout the somewhat crystalline matrix. A normal fault of 2 feet cuts across these two horizons. 6 feet.

3. A finer grained chert breccia, the fragments being from one inch in their greatest dimension down to the most minute, but it is clearly a breccia, for the fragments occur in great numbers and lie in all positions. Quantities of these are collected at various intervals into beds, the fragments becoming smaller and fewer upwards, but they end abruptly near the top. The matrix is a fine grained, gray limestone in layers of four inches to four feet. No calcite veins, looks like the Shenandoah. 45 feet.

4. A partly covered interval. Fine grained, light colored, medium bedded limestone with some shale partings. The calcite-veined chert extends to the base. The limestone beds are dove colored to dark blue and often have dark chert nodules, which sometimes are arranged in beds. There is some calcite veining in the chert. Toward the top of the section dark blue chert predominates with light colors more characteristic of the lower layers. There are open joints and bedding planes, and the usual weathered or water-rounded forms so characteristic of this formation. 243 feet.

Brachiopods were found about 50 feet above the breccia, hence low in this member, on the west side of New River.

5. Dark blue to black, fine grained, dense, non-crystalline limestone with the bedding concealed, and not developed by weathering. There is considerable black chert in nodules and in layers of nodules. These nodules, as well as the limestone itself, are veined with calcite. The chert is brittle and ferruginous, and both the chert and the limestone weather a rusty brown. Calcite is light and conspicuous. Jointing is meager. Pyrite crystals occur. 20 feet.

6. A very dark, blue black limestone with a hackly, rough fracture. Many valcite veins and some bundles of calcite crystals. The veins run in all directions, but the larger ones are at right angles to the bedding plane. Bedding is irregular. Pyrite crystals are common. 7 feet.

7. Fine, even grained, light gray to bluish limestone with close bedding. Fracture is smooth, fluted, and curved. This division looks and sounds flinty. Only a few calcite crystals and veins. No chert. Two layers; the upper being the lighter. Considerable pyrite, crystalline lenses in the middle portion. Weathers a light brown. 4½ feet.

8. Massive, light gray layer of fine grained, flinty limestone, with many small calcite veins, as well as some pyrite in scattered crystals and veins. Conchoidal fracture. Beds thicken and thin out locally. Weathers a little rusty but lighter than the rock. Boundary between 8 and 9 rather indefinite. 5 feet.

9. Massive, coarsely crystalline, dark blue limestone with cuboidal fracture. Bunches and veins of calcite occur, mostly in the joints. This division has the appearance of granite at a short distance. No chert or fossils. At one time this bed was used extensively for lime. Weathers a rusty grey. 16 feet.

10. Dark blue to black, thin bedded limestone, with many chert layers in black brittle nodules. Fine grained, calcite veined, fossiliferous matrix with the chert nodules, which weather out. Pyrite crystals, also brachiopods, cephalopods, crinoid stems, and corals. 15 feet.

11. Partly covered interval. A dense crystalline, dark limestone. Some chert and many calcite veins. Weathers almost white. Fossils as in 10, with the addition of gastropods. 83 feet.

12. Heavy bedded, blue limestone, one to seven feet in the thickness of the layers, cherty and calcite veined as well as containing large crystals of calcite. Master joints. Weathers rusty and deep, showing the weathering to a depth of forty feet. Fossiliferous. Bryozoans are the most abundant, but horn corals, crinoids, cephalopods, and brachiopods in several species occur. 89 feet.

13. Coarsely crystalline, mostly thin bedded, steel gray to blue limestone, with several thin shale partings. Very fossiliferous—especially towards the bottom, much as in No. 12. Thicker bedded toward the top, with calcite veins becoming abundant; no chert. 16 feet.

14. Shaly, steel gray limestone and calcareous shales, thin bedded. Very fossiliferous but fossils very much broken up. 2 feet.

15. One solid layer of dark blue, crystalline limestone, strongly calcite veined and carrying many broken and mashed fossils. 2 feet.

16. Thin bedded limestone, more or less argillaceous, with shale layers. The limestone is crystalline and very fossiliferous, especially near the base. Beds are for the most part under four inches in thickness. There is very little chert or calcite, and only a few joints. 20 feet.

17. Heavy bedded, dark steel gray limestone. Coarse and fine grained in different layers. Very much mottled with small clay lenses and streaks. Calcite veins occur complexly branching as well as chert nodules which are often cut by these veins. There are two joint systems at right angles to the bedding plane. Weathers with less rounding than the ordinary Chickamauga. Tetradium remains rather abundant. Beds 3-8 feet thick. Would quarry well. 50 feet.

18. Thin bedded, fine grained, cherty limestone, gray to black in color. There are many thin clay partings and beds or layers of chert nodules are characteristic. There are a few calcite veins. Weathers light. Fossils are rare. 20 feet.

19. A partly covered interval. Light to dark grayish blue limestone which is medium to thin bedded. Calcite veins and black chert nodules in layers. Bryozoans found. 105 feet.

20. Argillaceous limestone, showing thin beds grouped into layers of two to eight inches. The layers are alternately clay and

limestone. The color is grey blue. There are many white calcite veins and some pyrite crystals. No fossils or chert. Weathers light. 15 feet.

21. Thin bedded gray limestone, with thin shales, rarely veined with the exception of the bottom layer. Much mottled with small amorphous masses in a coarser crystalline matrix. Seems to be slightly conglomeratic. There are many fossil fragments; bryozoans, trilobites, crinoid fragments, brachiopods, corals, etc. 7 feet.

22. Coarse crystalline, light gray limestone, strongly veined with white calcite and some pyrite. There is no chert, but there are many fragments of fossils and some very whole and distinct, girvanella, brachiopods, bryozoans, trilobites and pelecypods. There is one mottled conglomeratic layer as in 21. The joints are irregular and are, for the most part, filled with calcite. The weathering emphasizes the amorphous inclusions. 4½ feet.

23. Dark blue to gray, fine grained, non-crystalline limestone, shot with numerous calcite veins. Bedding emphasized by weathering. Dip joints. Has clay conglomerate or breccia. Ends with layers about three feet above the first rocks which have the Moccasin appearance. 22 feet.

The samples collected from the various horizons of the Chickamauga limestone in this section show a remarkable uniformity in composition. The high lime content of these strata is indicative of their present exploitation in other parts of the state and of their future development here.

Analysis of Chickamauga Limestone,
Narrows section, Virginia[10]
(J. H. Gibboney, Analyst)

	1	2	3
Insoluble	5.60	1.50	2.30
Alumina, Iron oxide	0.78	0.56	0.60
Lime	51.40	54.76	54.06
Calcium carbonate	91.80	97.78	96.54
Magnesia	0.72	0.15	0.30
Magnesium carbonate	1.52	0.31	0.64

[10] Bassler, R. S., "Cement Resources of Virginia." pp. 189.

The Moccasin Limestone

The Moccasin Limestone, correlated with the Athens Shale and the Tellico Sandstone of Eastern Tennessee, marks the transition from the hard blue limestone of the Chickamauga to the Sevier calcareous shales. The formation is composed of red and greenish blue earthy limestones having a mottled appearance, and always weathering with a characteristic hackly appearance. These limestones usually outcrop on the steep slopes of the valley ridges and thus give a pronounced color to the landscape. The formation occupies a position stratigraphically intermediate between the great limestones beneath and the shales and sandstones above. The exposed surfaces are often ripple marked or mud cracked, indicating that the seas were much shallower than before and at their minimum depth for a limestone to be formed.

These limestones take their name from Moccasin Creek, Scott County, Virginia. In thickness, they vary from 300 to 500 feet, being 344 feet thick at the Narrows. There are several layers which are of proper texture and composition to have value as lithographic limestones but are too thin and fragmented. They have been tried as such by the U. S. G. S. Towards the top of the formation, there are alternate limestone and shale beds in which the limestone is gray blue, resistant with a hackly fracture and splintering into fragments because the jointing is not at right angles to the bedding plane. The shale horizons are very weak, the red and yellow beds weathering rapidly into very sticky clays. The entire formation exhibits the splintery fracture described above. Calcite veining occurs, but is not a dominant feature.

Paleontology and Correlation

For some time, the Moccasin limestone has been regarded as a transition formation between the great development of Ordovician limestones in the Powell valley and the equally great development of shale and sandstone in the eastern portion of the Appalachian Valley. If this were the case, and continuous exposures could be had, the formation should grade into lime on the west and shale in the east. Recent investigations show that this is not the case and that the Moccasin is but a single Ordovi-

cian formation.[11] Certainly, there is no appreciable gradation in Giles County.

Fossils are rare, but specimens of *Dalmanella testudinaria* and *Plectambonites sericeus* were found as well as fragments of *Triarthrus becki.* What faunal evidence there is, as well as the stratigraphic position of this formation, indicates a Mid-Ordovician age, equivalent in part, at least, to the lower Utica division of the New York classification.

The Moccasin Limestone Subdivided

Section taken at the Narrows of the New River, Giles County, Virginia. First two members are on Virginian Railroad.

1. Bluish limestone, thin bedded and not obliquely jointed as in the rest of the formation. The last two feet of this division are separated from the rest by three or four layers which resemble the Chickamauga. Even bedded and calcite veined. Mud breccia in this member. 10 feet.

2. Red to light brown, fine grained, even bedded limestone. Jointing is oblique with splintery fragments which are emphasized by weathering. A few layers are bluish gray instead of reddish. Beds are from one to fifteen inches in thickness. One layer of hard, drab to grey lithographic limestone four inches thick about twelve feet from the bottom. Mud cracks are unusually prominent. 90 feet.

3. Lithographic horizon. Starts up the ravine leading from railroad to wagon road.

   a. Hard, dense, blue, limestone layer with small calcite veins. 6 inches.

   b. Continuation of normal Moccasin. 10 feet.

   c. Second fine grained, hard, lithographic layer, cherty appearance. 1 inch.

   d. Continuation of normal Moccasin. 1 ft. 8 inches.

   e. Third lithographic layer. 2 inches.

   The non-lithographic layers seem to be partly lithographic, but of an inferior quality. Total, 12 feet, 5 inches.

4. Gray, greenish to drab, hard limestone in beds three to twelve inches in thickness, weathering lighter and having the same oblique jointing and splintery fragments as noted elsewhere. 16 feet.

[11] Bassler, R. S., 'Cement Resources of Virginia." pp. 167.

5. A covered interval on wagon road with soft shaly limestone and calcareous shale in the float. 117 feet.

6. Limestone and shales alternating. Six limestone horizons of gray to blue resistant beds. No chert nor calcite and rarely fossiliferous. Argillaceous and breaking into splintery pieces because the jointing is both at right angles and oblique to the bedding. Six shale layers of soft, crumbly, yellow and red material, weathering into a reddish yellow, sticky mud, which covers up the slopes.

Shales	17	feet (bottom)
Limestone	10	"
Shales	18	"
Limestones	1	"
Shales	3	"
Limestones	3	"
Shales	10	"
Limestones	4	"
Shales	6	"
Limestones	5	"
Shales	3	"
Limestones	8	" (Top)
Total	88	"

Analysis of Moccasin Limestone from the Pearisburg section[12]
(J. H. Gibboney, Analyst)

	1	2
Insoluble	11.73	7.66
Alumina, Iron oxide	1.48	0.82
Lime	47.78	50.38
Calcium carbonate	85.32	89.96
Magnesia	0.24	0.35
Magnesium carbonate	0.58	0.76
Total	99.11	99.20

1. Impure, drab limestone.
2. Red, clayey limestone.

[12] Bassler, R. S., "Cement Resources of Virginia." p. 194.

The Sevier Shales

This formation, showing the transition from limestones to sandstones above, forms the steep slopes of the larger valley ridges. It takes its name from Sevier County, Tennessee and corresponds with the late middle and upper Ordovician of New York, that is, the late Utica and Eden shales. It is also probably equivalent to the Maquoketa shales in Iowa as well as part of the lead and zinc bearing formations known as the Galena limestones.

This formation, which varies from calcareous shales at the base to sandy shales at the top, is from 1250 to 1500 feet in thickness, the section at the Narrows measuring 1341 feet.

These shales are fossiliferous throughout, corals, graptolites, sponges, bryozoans, and cephalopods being found rather commonly. In the upper layers trilobite fragments are found and pelecypods are common. Brachiopods are found throughout. *Plectambonites sericeus* is especially numerous and seems to be characteristic of certain beds in the formation.

The shales are interbedded with thin limestone layers in many places, and on the whole the formation is weak and non-resistant as well as being thin bedded throughout. Like the Russell formation, these shales are also folded and contorted. The bedding is clearly defined but the jointing is not conspicuous except where it forms cuneiform pits. Blue, brown, green and gray color combinations are the most common ones, with calcite veining rather marked in some places.

This formation passes up into the overlying sandstones rather abruptly and thus the dividing line is not so difficult to establish at the top as at the bottom, where Moccasin conditions seem to reappear several times after many feet of Sevier shales.

Paleontology and Correlation

In Sevier County, Tennessee, the formation overlying the Tellico, has been named the Sevier. This formation is not very fossiliferous ordinarily, but has a fairly well developed fauna in Giles County. Fragments of *Triarthrus becki, Plectambonites sericeus, Rafinesquina alternata, R. squamulata, Calymene* sp. and *Zygospira* sp. are most commonly found but both *Didymograptus* and *Monograptus* types of graptolites are also present.

From the faunal evidence, the shales are late middle or upper

Ordovician. The fauna, (what little can be found) of the Moccasin is also present in the Sevier so that there is no great difference in the age of these two formations. Late Utica, Eden and possibly early Lorraine, seem to be the times in the New York Ordovician scale, which are comprised in the Sevier of Giles County.

The Sevier Subdivided at the Narrows Section.
Wagon road above Virginian Railroad

1. A hard, blue, even-bedded non-fossiliferous limestone, exhibiting the characteristic Sevier cleavage. One layer. 1½ feet.

2. Gray, crumbly shale, weathering to clay. 2 feet.

3. Even-bedded limestones and shales. The former in four to eight inch layers, blue to dark blue, hard, and all but non-fossiliferous. The shales are in two layers, one being green and the other yellow, besides many shale partings. The jointing gives cuneiform pits in the limestone. Fossils begin in this horizon. 18 feet.

4. Calcareous shales and thin limestones like the upper part of this formation, but more of a greenish gray color, and more crumbly. Soft with few fossils. This is the end of the transition from the Moccasin. A partly covered area. 20 feet.

5. Blue limestone in beds of one to eight inches. Fossils uncommon. A little shale and some calcite veins. 8 feet.

6. Shale with a slaty cleavage, dark blue, green and black in color. Fissile, much jointed and thin bedded. The shale is rather calcareous. Fossils are rare. 19 feet.

7. Thin limestones with a few interbedded thin shales. The limestones one inch to one foot in thickness, being dark gray to blue but weathering lighter and leaving much residual clay. Calcite veins are numerous and branching and some are as much as an inch and a half in thickness. This division is fossiliferous with the shells being much broken. The veins and fossils both weather out. Much jointed and cracked. Shale partings occur and are from paper thickness up to six inches, but they are not arenaceous. The beds are bent, crumpled, and folded as well as being faulted locally. Very fossiliferous. The brachiopods *Dalmanella testudinaria* and possibly *subaequata* and *Plectambonites sericeus* being very common and characteristic. 386 feet.

8. Thin limestones, one to twelve inches in thickness, interbedded with thin blue shales. More than half is limestone, hard, dense, blue, fossiliferous and calcite veined. Talus consists of limestone almost entirely. The limestone layers thicken and thin and are sometimes bent so as to reverse the dip. Several small concretionary layers are present. The upper feet are more limey and thicker bedded. In the central portion *Monticulipora* sp. are common and toward the top there are several species of coral. In the lower portion many graptolites of the *Didymograptus* and *Monograptus* types, *Asaphus gigas, Rafinesquina alternistriata, Chaetetes* sp., *Lophospira* sp., *Bellerophon* sp., and *Orthoceras* sp. are found. 224 feet.

9. A series with more shale than limestone, in little beds, none of which are more than one inch in thickness. Only about forty feet of this horizon is exposed. Fossils found are *Calymene* sp., *Raphistoma peracutum* and a *Monticulipora* species. 175 feet.

10. Alternating shales and thin limestones much like layer number 12. There are no distinct layers and the divisions are marked by numerous small faults of less than 15 inches. 123 feet.

11. Contorted limestone beds with interbedded calcareous shales and limestones. There are six layers, two near the bottom are two feet thick, then there are three layers, two to three feet thick, and a single three foot layer at the top. The fourth layer from the bottom has a conglomeratic phase near its top which was seen in both the railroad and wagon road cuts. Fossiliferous. Calcite veined. The limestone is blue while the shales are brown and greenish grey. 85 feet.

12. Calcareous shales, thin bedded, blue, greenish and brown, with many thin blue limestone layers full of fossils. The limestone weathers rapidly by solution leaving clay where the limestone layers were. Thus the limestones are usually indented in a weathered cut. Calcite veins are very abundant. 80 feet.

13. A limestone layer, grey to olive green and jointed so as to give "V" shaped notches and the cuneiform pits, 1-6 inches wide and 1-20 inches long. Surface weathers smooth but sharp angled corners project. 2 feet.

14. Calcareous shales containing a few layers of hard blue limestone. The limestone is very fossiliferous and in beds

6-12 inches thick, and contains calcite veins. The shales are gray, green and indifferent tints, and also fossiliferous. There are many thin sandstones 1-3 ft. thick jointing into regular angular and cubical blocks. The shales weather rusty and the limestone weathers by solution leaving fossil cavities and red clay.

113 feet.

15. Thin bedded, greenish, gray blue, calcareous shales with thinner, stronger layers mainly of flinty sandstone but none of limestone. There are many fossiliferous horizons some of which weather out porous. Brachiopods, pelecypods and bryozoans occur. 44 feet.

16. Thin bedded, bluish green, calcareous, and sandy shales with thin 2-4 in. sandstone layers every foot or two. These latter weather out in angular pieces like chert layers. There are many fossil zones and scattered fossils throughout the whole horizon. 18 feet.

17. Thick bedded, massive, dark olive green, calcareous sandstone in some places weathering shaly and in others like sandstone. There are many horizons of broken and well-preserved fossils. Brachiopods occur 6 ft. from the top. The rock is richer in fossils than the Bays. 19 feet.

The following analyses of the Sevier Shales will serve to indicate their approximate composition at the Narrows although the samples listed below were taken near Goodwins Ferry which is more than 20 miles up the New River.

Analyses of the Sevier Shale[13]
(J. H. Gibboney, Analyst)

	1	2	3
Insoluble	5.12	41.48	71.88
Alumina, Iron oxide	2.92	6.04	8.56
Lime	51.16	28.00	8.54
Calcium carbonate	91.39	40.00	15.25
Magnesia	0.25	0.30	1.27
Magnesium carbonate	0.53	0.64	2.68

1. Thin bedded, blue limestone, lower part of the Sevier.
2. Calcareous shale from the lower horizons of the formation.
3. Sandy shale from the Eden horizon of the Sevier Shale.

[13] Bassler, R. S., "Cement Resources of Virginia," p. 200.

The Bays Sandstone

The sandstones and shales overlying the preceding formation are for the most part, red, yellowish red, or purplish red, but there are some green blotches which resemble, but are not, surface features. The thin bedded sandstones at the top pass downward into sandy shales, keeping the prevalent color and merging at last into the Sevier below. The formation takes its name from Bays Mountain in Tennessee.

This sandstone scratches very easily and weathers shelly. Some layers show cuneiform jointing developed to an unusual degree, and the jointing is good throughout, there being master joints in several localities. In some places, the sandstone is slightly quartzitic but for the most part the formation has been but very little metamorphosed. The fracture is usually uneven to conchoidal.

The conditions were not especially good for life development during the time these rocks were laid down, nor is the formation a good one for preserving fossil forms had life been present, hence fossils are found mostly in the lower, more shaly layers. There are several very distinctive nodular layers and cross bedding is quite noticeable as well as ripple marks, all indicating shallow seas. In the top layers, there are fine flakes of primary mica as well as some secondary chlorite along joint and bedding planes. The total thickness of the formation at the Narrows is 321 feet.

Usually the crest of the ridges is formed of Clinch, with the red Bays outcropping below, but in some places, especially in low gaps, the Clinch has been eroded away and the summit is then formed of the Bays Sandstone.

Paleontology and Correlation

Fossils in some of the lower layers are well preserved and fairly numerous. *Hebertella sinuata* and *Orthorhynchula linneyi* are found throughout, as well as a large, unidentified ramose bryozoan.

It would seem from the faunal evidence as though the Bays was either Lorraine or Richmond in age. Lorraine forms seem to predominate. If this correlation is correct, the Bays sandstone of Giles County is younger than the typical Bays of Tennessee,

which is beyond question Middle Ordovician (Black River).[14] In this case, the name Bays is a misnomer, as applied to these red sandstones of Giles County. In northwestern Virginia, the name Juniata has been applied to a similarly situated red sandstone, whose age is beyond doubt lower Richmond. It would seem, then, that the name Juniata might be used here rather than Bays.

The Bays Sandstone Subdivided
Narrows Section. (Wagon road)

1. Medium bedded sandstone with thinner shales, green blotches becoming bands in places. Even bedded, several layers carrying broken fossils, red with iron. Base of formation marks the change in color from dark red to green. 20 feet.

2. Thin bedded, purplish shaly sandstone, carrying several beds of broken shells. Trilobite fragments are common. A ferruginous layer. 9½ feet.

3. Lower nodular layer flattened, concretionary-like masses one to two inches thick and six to ten inches broad. These are not concretions, and do not take the iron rust on the curved cleavage faces as do those of similar appearance in the upper nodular layer. The upper and lower parts are the richest in these masses and are the most shaly. The middle is more massive and sandy with conchoidal fracture and many green blotches. Fossils are in fragments in the upper portion. 5½ feet.

4. Cross bedded layers of dark red sandstone with thin interbedded shaly sandstone layers. All are cross bedded even to great wedge-shaped masses of many layers. Some ripple marks, and much chlorite in the joint planes as well as some on the bedding planes. Quartz is also found deposited in veins. Slickensides along some bedding planes. 32 feet.

5. Thin sandstone layers which are arenaceous, micaceous, and shaly. This division is dark red, thin bedded and crackled, and much shot with minute joints. When it is freshly exposed, it resembles a single massive layer, but with weathering it crumbles into fragments. Top layer is a thin green shale. 2 feet.

6. Upper nodular layer. Dark red sandstone, upper one and one-half feet massive, even grained and breaking with curved surfaces which scratch very easily. Middle two feet are nodular

[14] Stose, G. W. and Miser, H. D., "Manganese deposits of Western Virginia," pp. 29.

and look concretionary but are not. Curved pieces break out giving rounded masses, but each has the same composition as the rock above and below. Red, ferruginous quartzitic sandstone with quartz veins. Weathering of the iron has gone on along these curved planes and thus has aided the spheroidal breaking. The lower two feet are rarely nodular but otherwise they have the same appearance. 5½ feet.

7. Red sandstone and arenaceous shales, which when first exposed, seem to be thick, massive beds. When weathered, the thin shaly beds appear and the rock crumbles. Fine and even grained with little cross-bedding. Regular for long distances. Usually dark, brick red, rarely gray. Scattered green blotches occur as well as calcite veins. Fine flakes of mica are probably primary but the chlorite veins are secondary. 47 feet.

8. A covered interval, which from the float seems to be largely soft gray and green as well as red sandstones and shales. 197 feet.

Analyses of a Single Sample of the Bays Formation from near Glade Springs, Virginia.[15]
(J. H. Gibboney, Analyst)

	Per cent
Insoluble	90.18
Alumina and Iron oxide	5.72
Lime	0.64
Calcium carbonate	1.14
Magnesium	0.03
Magnesium carbonate	0.07

THE SILURIAN SYSTEM

Introduction

The Silurian rocks of Giles County are dominantly sandstones, (sometimes semiquartzitic), but there are also interbedded shales, and a few conglomeratic layers. These rocks are divided into the Clinch and Rockwood formations, but in addition some rocks classed as the lower Giles may be in part Silurian.

Silurian strata outcrop in a continuous band, about a mile and a half wide, along the northern border of the county, but do not extend into the panhandle because they dip south and thus in

[15] Bassler, R. S., "Cement Resources of Virginia," p. 170.

the valley they are carried south. They are also present over a considerable area in the eastern as well as the western mountain areas, but their outcrop on the Walker Mountain range lies only in a narrow strip which is very restricted in Giles County.

The Clinch and the Rockwood are both mountain making rocks and they are usually found capping ridges. Iron ore of the Clinton type is found in the Rockwood but has not been exploited to any extent here. There are about 550 feet of Silurian strata in Giles County.

The Clinch Sandstone

The Clinch Formation, taking its name from Clinch Mountain, is found throughout the entire Appalachian system. It corresponds to the Medina Sandstone of New York. All the important valley ridges owe their existence to this heavy plate of sandstone which has preserved summits at or nearly at the level of the oldest recorded peneplain, while adjacent areas have been eroded to the present valleys.

This formation is easily separable from all the others because of its massive character. It usually varies between 125 and 300 feet in thickness, there being 140 feet in the Narrows exposure.

This rock is a semi-quartzitic sandstone, coarse to fine grained, sometimes conglomeratic with large quartz pebbles. Slickensides are rather common because the beds are so stiff that they break and slide over each other rather than bend. The formation weathers light brown to yellowish bronze color, red and purplish red occurring in places. It has an uneven fracture, is fairly even bedded, and very dense and resistant. These rocks form the larger rapids at the Narrows of the New River.

The formation contains arenaceous shale layers which become more numerous towards the top. While fucoids are found in some places, the formation may be regarded as practically nonfossiliferous.

Paleontology and Correlation

The Clinch thickens off to the north and east, so that while in Giles County its thickness is 140 feet, it is 300 feet thick in northern Virginia where it makes Cacapon Mountain. On Massanutten Mountain, sandstones of equivalent age are called Massanutten, while in Pennsylvania and Maryland, the same formation is known as the Tuscarora sandstone.

Fossils are rare, but some specimens of *Lingula cuneata* can be found in the shaly division. Excellent specimens of *Scolithus verticalis* and *Arthrophycus harlani* have been found on Angels Rest and Peters slopes. What faunal evidence can be found then, as well as stratigraphic position and lithologic character, seem to indicate Medina age for the Clinch.

The Clinch probably rests unconformably upon the upper Ordovician Bays sandstone.

The Clinch Sandstone Formation Subdivided
Narrows Section

1. Lower part of Clinch. Sandstone in layers from one inch to eight feet, with thin arenaceous shale partings, one-fourth to three inches in thickness. Colors are gray and greenish blue as well as a purplish gray and it is not until weathered that the formation assumes the bronze red tint due to the iron impurities. Quartz pebbles cemented with iron, silica and colored by the iron are metamorphosed into a fair quartzite. The pebbles attain a size commonly equal to that of a hickory nut, rarely 2-3 inches in diameter, and are of older quartzite and vein quartz. There are some minor faults in this division. 120 feet.

2. Upper layers. Five shale layers, nearly four feet thick, all arenaceous, in variegated colors of green, blue, red and brown as well as various tints, and being thinly laminated—separated by four layers of quartzitic gray sandstone of about six inches in thickness. These beds vary notably from place to place. 20 feet.

The Rockwood Formation

This formation takes its name from Rockwood, Tennessee, where it has been used as an iron ore for many years. It is a heterogeneous mass of shales and sandstones, corresponding to the Clinton formation with its iron ore of New York and Alabama. In the Narrows of the New River, 292 feet of this formation are exposed but in some localities its thickness runs as high as 400 feet.

In some places, the sandstone is semiquartzitic, and such a layer forms the upper rapids in the New River at the Narrows. The jointing is good and is for the most part cuboidal. The dominant color of the formation is red on account of the large iron content. These rocks are fossiliferous to some extent, fucoids,

bryozoans, brachiopods, pelecypods, trilobites and corals being recognizable but in many places the fossil remains are too fragmentary to be identified.

The Rockwood is extremely thin bedded in some localities but the average bedding is medium. Ocherous sands occur in places and several layers could be used for building purposes with excellent results. One quartzitic layer with a conglomeratic phase is very similar in every respect to the Clinch.

Many of the higher ridges are capped with Rockwood which is sometimes the source of the mountain iron ore. The ore, however, is in this locality either of such low iron content or is so inaccessible that it promises no definite economic value for years to come. In the case of the Rockwood ore, it seems as if the upper layers in being eroded away have left their iron content to be leached down into the lower layers and thus they are always the richest ones.

Paleontology and Correlation

Fossils are usually quite numerous in the Rockwood, but in Giles County only a few were identified. The age of these fossils is Clinton. In some places in the state, rocks of Cayuga age have also been called Rockwood, but in Giles County, this formation is entirely Clinton.

The white quartzitic layer near the top is thought by Stose and Miser[16] to be of the same age as the Keifer sandstone of Pennsylvania and Maryland.

The Rockwood Formation Subdivided

Narrows Section—Wagon Road

1. Thin shales and argillaceous thin sandstones, in a variety of colors, such as blue, red, and green. Weathers to sandy mud. Much jointed and crumbly. Several red sandstone layers in the shales. At the base are found *Camarotoechia neglecta* in two zones about eight feet apart, very abundant but quite alone. About 75 feet above these fossil beds a rich fossil horizon occurs carrying *Anoplotheca plicatula, A. hemispherica, A. plano-convexa, Chonetes cornutus, Liocalymene clintoni, Buthotrephis gracilis,* var. *crassa* and var. *intermedia.* About 114 feet above the base are found *Bumastus barriensis, Calymene blumen-*

[16] Stose, G. W. and Miser, H. D. "Manganese Deposits of Western Virginia." pp. 30.

bachii, Liocalymene clintoni, Beyrichia lata. This array of forms establishes the Clinton age for the Rockwood, and suggests that the lower Rockwood is the equivalent of the middle or upper Clinton of New York. 120 feet.

2. Dense, quartzitic sandstone in three or four layers, one of which is about 18 inches thick. The sandstone is coarse grained at the base. 3 feet.

3. Ferruginous shales and sandstones in alternate beds. The average color of the sandstones is red. The shales are thin, gray and green. 18 feet.

4. Dark red, ferruginous, quartzitic sandstone, irregularly bedded and jointed. Weathers to a rusty brownish red. Irregular blocks as large as five feet thick weather out. Hematite in certain places. 5 feet.

5. Alternating sandstones and shales. The sandstones are two to five inches thick and are red and grey, dense and quartzitic. Regular cuboidal jointing into brick like blocks. Thin shale beds of a smooth greenish gray color and not sandy. Bryozoans are common. Fucoids? 6 feet.

Section described now goes to Virginian cut.

6. Shales, having soapy feel, without grit. Gray, green and yellow, weathering soft, punky almost black. Thinly laminated. Brachiopods. 13 feet.

7. Layers of blue, gray, and pink, dense quartzitic sandstone, with a little shelly material in the upper half. Weathers a dark brown and red. *Atrypa reticularis.* 6 feet.

8. Coarse buff sandstone, not cemented and not quartzitic with ferruginous veins with crooked branching, which seem to be impregnation of the natural pore spaces between the grains of sand. Iron is more abundant and much darker red than usual in this division. There are many cavities an inch or less across. The rock is thin bedded but one layer in the middle part is 2 — 2½ feet thick. Possible bryozoans were found. 7 feet.

9. Gray sandstone, with fine gray blue shale layers. The sandstone is quartzitic in beds of two to eight inches. One group seems to be a heavy one but shows thin when weathered. Near the bottom several layers are a pronounced red and weather rusty. Strong cross bedding. No fossils. 15 feet.

10. Black, carbonaceous, shaly layers, as well as red, brown and gray ferruginous layers. It is always sandy with quartz

grains rounded and some of the cavities are quartz filled. A few red sandstone layers. The shale is fissile, thin bedded and weak. Fossils found but badly mashed. 7 feet.

11. Strong sandstone layers, one to six inches thick, gray, reddish and mottled. Weathers a dark red and rusty. Layers are even and continuous. Very thin, sandy shale partings. Pelecypods. 2 feet.

12. Soft, shaly sandstone in thin beds, weathering easily into clayey sands. Dark gray, yellowish and brown. Brachiopods. 2 feet.

13. Ripple maker. Resistant gray quartzitic sandstone with pink lines and gray mottling, heavy and cross bedded. Heavy pebbles in a fine grained matrix and resembles conglomeratic layers of the Clinch. Cavities of considerable size are more or less filled with chalcedony and quartz crystals. No fossils seen. 9½ feet.

14. Covered interval of soft shaly material. 38 feet.

Near the base were found *Tentaculites minutus*, and *Tellunomya lata*.

15. Layers of purple and red, quartzitic sandstone. Fine bedding lines of alternate light and dark red often are apparent. Two to six inch layers grading off thinner and weaker toward the top. Weathers a rusty bronze. 7½ feet.

16. Three to six layers of dense, hard red to purple quartzitic sandstone, even bedded and fine grained. Some of the layers split up on weathering into two or three layers. Would make a handsome building stone as it weathers a beautiful bronze. There is one greenish layer. 3½ feet.

17. Between fifty and seventy layers of slightly argillaceous sandstone and quartzitic sandstone, becoming thinner and weaker towards the bottom. 2 feet.

18. Strong quartzitic sandstone beds two to eighteen inches in thickness and slightly crackled and broken. Gray, greenish and red in streaks. Weathers rusty, reddish and rough. Five feet from the top is a layer of loose material, caused by the weathering and leaching of a more porous layer. Ocherous sands in some places; in others apparently concretionary. It probably is not concretionary but is a residual structure brought out by weathering. Corals near the bottom. 15 feet.

19. Thin bedded sandstones with little shale partings; sandstones one-fourth to five inches thick. Buff to gray with no red. Weathers a uniform buff. Shattered and crackled but there are no master joints. Some layers are quartzitic but some are also loose sands. Some layers have the appearance of one in unweathered surfaces. Myriads of *Cytherellina* in the middle.
13 feet.

This does not complete the section, as a part of the Rockwood is faulted out. On the west side of the river the fault continues westward but is some distance farther south so as to leave all the Rockwood and a considerable section of Giles north of the fault. There may well be, then, 100 feet or more of Rockwood missing.

THE DEVONIAN SYSTEM

Introduction

The outcrops of Devonian strata are confined to restricted exposures having a general northeast southwest strike. One of these outcrops is on the northern flank of Brushy Mountain, another extends into Giles County from Bland on the west, and appears for some little distance to the east of the Stange mine on Flat Top Mountain. Still other outcrops are found in the upper courses of Clendenning, Little Stony, Stony, and Johns Creeks, as well as in a small strip across the Panhandle. In the south slopes of East River Mountain are considerable areas of Giles beds extending from New River almost to the Bland-Giles county line.

There are no good sections of lower Devonian exposed in Giles County so that there is some confusion as to the exact age of the Giles formation. Some of the rocks which appear above the Clinton, and are almost certainly Cayugan in age, are classed as Giles, yet the upper Giles bears a marked resemblance faunally, stratigraphically, and lithologically to the Oriskany. There are also occasionally limestones and cherts below this sandstone which have been referred to as Helderbergian.

The Oriskany formation is of importance since it is in this horizon that many of the manganese prospects of the county are located. The other divisions have no economic value. The entire Devonian as observed in this area is less than 3000 feet in thickness, but it occurs in such scattered outcrops, and in places is so faulted that this figure may be either too large or too small.

Limestones to limey shales, to black shales, grading at last to sandstones at the top, constitute the normal succession of Devonian strata in Giles County.

The Giles Formation

Above the Rockwood is a group of strata of diverse characteristics, but hard to separate in the field. In the Kimberling Creek area, in the western portion of the county, there is at the base of the Giles some forty feet of blue limestone, calcareous shale at the base but heavy limestone at the top. This is followed by coarse, ferruginous sandstone, some fifteen feet in thickness, made up of small quartz pebbles. Above this, there is cherty limestone, about thirty-five feet thick, which is always present along the outcrop and is the key to the subjacent strata, and following this, there is an undetermined thickness (probably less than 100 feet) of yellow-green sandstones.[17]

Paleontology and Correlation

Little time was spent on the fauna of the Devonian formation. The upper divisions of the Giles are Oriskany and Helderbergian in age, but the two lower divisions, as described above are without faunal record in Giles County. On the south slope of East River Mountain, between Narrows and the west county line, there are many exposures of the beds grouped as Giles. They are cut somewhat parallel to Wolf Creek by a fault so that their resistant layers repeat in places to form several rocky ridges. Farther west in Wolf Creek Valley and quite near the county line the Giles outcrops in two strips with Rockwood above the northern strip and again between the strips, while Shenandoah appears to the south. A fault has let the Giles down against the Rockwood, thus preserving it. Erosion has removed the Giles from a part of the Rockwood farther down the slope and a large fault near Wolf Creek has carried the Shenandoah up to the height of the Giles. In these areas considerable detailed work has been possible, and the following correlations have provisionally been made:

1. Blue calcareous beds varying from firm limestones toward the top to weak shales at the base, and resting immediately on the Rockwood. 40 feet ±

[17] Campbell, M. R., U. S. G. S. Folio No. 26.

2. Rather even bedded sandstone and coarse but even grained sands well cemented with iron oxide. Many molds of pelecypods in the main poorly preserved. 20 feet ±

3. Limestone and chert. Whole beds are of chert, others are a chert breccia with a meagre limestone matrix. In no place was number 4 present with number 3 eroded away. Fossils were found in the chert only. The colors are red, tan, pink, yellow and gray. The bedding is irregular to imperfect. 40 feet ±

4. Coarse yellow, buff, tan and green sandstones in part loosely cemented, in part almost quartzite (boulders travel long distances in the float). Many molds of *Spirifer mucronatus*, with hinge line much extended and a few *S. arenosus*. Some of the beds are shaley but the member is for the most part sandstone. 100 feet ±

These four members were found together in two or three places and one or more of them were recognized repeatedly but they never could be traced far. They became covered with their own waste or float from the Rockwood. Nevertheless the group as a single map unit was placed on the map almost all the way from the river west to the county line. The area varies greatly in width because in many places the greater part of the Giles has been eroded away from the Rockwood.

It seems reasonable to correlate No. 1 with Coeymans, No. 2 with New Scotland, No. 3 with Becraft and No. 4 with Oriskany, but any such allocation is only tentative. No. 4 and Oriskany are the most confidently connected. There is much less assurance concerning the other three.

There seems to be an unconformity at the base of the Oriskany, but the details of the occurrence or absence of different parts of the Cayuga and Helderberg are not well known in this area. It seems to the writers that future work here will justify a revision of the nomenclature of the lower Devonian which may result in at least three new division names for rocks which are at present simply called Giles.

The Romney Shale

Overlying the Giles, there are in a few places in Giles County, dark shales to which the name Romney has been given. These shales grade insensibly from black carbonaceous shale, which is

replaced by green, sandy shale, to rocks which in turn merge into thin bedded green sandstones. Only the dark division is called Romney, the upper portions being designated as Kimberling.

The true Romney shale at the type locality, Romney, W. Virginia, is reported to contain fossils of Onondaga, Marcellus, and Hamilton age. The Romney of Giles County is thought by Stose and Miser to be of Genessee and lower Portage time and therefore younger.[18] At the base of the Romney, however, near Big Stone Gap there have been found fossils of Hamilton and Marcellus age in a thin layer of disturbed, rusty, black shale. True Romney has been deposited, it would seem, but has almost entirely been removed by erosion. The thickness of the so-called Romney is about 500 feet.

Again, exposures in Clendenning Creek are clearly of Marcellus age for they contain the following forms: *Camarotoechia* cf. *exemia, Stropholosia truncata, Leiorhynchus limitare, Styliolina fissurella, Tentaculites bellulus,* and *Ambocoelia umbonata.* These include forms said by Kindle[18a] to be characteristic of the Marcellus. To continue, none of the forms said by H. S. Williams to be characteristic of the Genesee have been found in the Narrows section. Hence, the evidence from both sides seems to point to Marcellus age for the Romney of Giles County.

The Kimberling Shale

As has been mentioned before, this formation passes from greenish or gray fissile shale to sandstone and appears to be about 3000 feet in thickness. Fossils, which are not numerous in this formation, indicate Portage and Chemung age. The sandstone at the top may in part be Catskill although no flora or fauna were found in this horizon.

None of the Devonian of Giles County presented outcrops which could be subdivided easily since by far the greatest portion of these rocks is shale which weathers very rapidly.

[18] Stose, G. W. and Miser, H. D. Manganese Deposits of Western Virginia. pp. 38.

[18a] Kindle, E. M. Jour. Geol. Oct.-Nov. 1906. Faunas of Devonian Section near Altoona, Pa.

THE MISSISSIPPIAN SYSTEM

Introduction

The Mississippian formations, which are the youngest consolidated sediments of Giles County, appear only in the panhandle district. The base of the series is sandstone, which is followed in turn by shales, limestones, more shales, and is, in this area, terminated by the Hinton formation. The total thickness in Giles County is less than 4500 feet, but it is very hard to measure on account of the covered areas.

The Price Sandstone

Overlying the upper Devonian sandstones, there is a granular, bluish white sandstone which contains scattered quartz pebbles. This sandstone is continuous with one in Bland County (of apparently the same age) which has been called Price by Campbell.[19] In other parts of Virginia, a sandstone very similar to the Price, and of basal Mississippian age has been given the name Pocono. The writers believe that the two are of the same age and are a stratigraphic unit.

No fossil plants or invertebrates were found in this division.

The Pulaski Shale

This is a bright red shale, which is usually brought in direct contact with the middle Price due to the faulting out of the upper portion of the latter formation. This, however, is not the case in the Narrows section, and yet only a poor exposure of what was thought to be Pulaski could be found, due again to the rapidity with which those shales weather to cover themselves.

The Greenbrier Limestone

This formation is made up of heavy blue limestones, which are sometimes cherty and always fossiliferous. At the top, however, it becomes rather shaly and passes into a calcareous shale at the base of the overlying formation. Several considerable sandstone horizons also occur in the Greenbrier.

Paleontology and Correlation

Some of the more common faunal forms of the Greenbrier of Giles County, as listed by Bassler and others, are given in the list which follows:

[19] Campbell, M. R. U. S. G. S. Folio No. 26.

Spirifer increbescens	Zaphrentis spinulosa
Eumetria marcyi	Fenestella sp.
Seminula subquadrata	Archimedes sp.
Seminula trinuclea	Derbya crassa
Productus fasciculus	Allorisma maxvillensis
Productus cestriensis	Bellerophon sublaevis
Pentremites godoni	Spirifer keokuk
Pentremites pyriformis	Dielasma turgida

Professor Prosser and Dr. R. B. Rome collected a very similar fauna from the Greenbrier of Maryland for the state survey. The Maxville limestone fauna of Ohio is also very similar and the Greenbrier has been regarded as the Appalachian equivalent of the Maxville by Morse[20] and others. This is no doubt in part true, but the Greenbrier seems to include more than the Maxville.

The Greenbrier as Divided by Bassler[21]

Probably the best and most detailed section of the Greenbrier limestone to be observed in Virginia may be seen along the Norfolk and Western Railroad near Lurich, in Giles County. Here all of the beds are fairly well exposed and the section may be considered as typical for the region. For this reason all of the variations in the strata at this point were noted. The section is, in ascending order, as follows:

Geologic Section, Greenbrier Limestone
Vicinity of Lurich, Virginia

7. Thin-bedded blue limestone with beds of blue and yellow shale. 400 feet.
6. Compact blue to black argillaceous limestone in thin flaggy layers, much fractured. 170 feet.
5. Compact blue-black, fine-grained limestone alternating with coarsely crystalline fossiliferous strata, with blue limestone and yellow shales in upper part. 150 feet.
4. Drab and blue shales. 80 feet.
3. Massive blue and argillaceous limestone with a few shaly beds in the upper part. No chert observed. 90 feet.
2. Drab and yellow calcareous shales with occasional bands of compact blue limestone. 180 feet.

[20] Morse, W. C., "The Maxville Limestone," Bull. 13, Series No. 4, Ohio Geol. Survey, pp. 109-111.
[21] Bassler, R. S., "The Cement Resources of Virginia," pp. 275.

1. Dark blue to black, heavily bedded limestone with many small chert nodules. *Productus, Zaphrentis,* and *Fenestella* observed. 175 feet.

The Bluefield Shale

This shale, which directly overlies the Greenbrier, varies from calcareous at the base to sandy at the top, where it is capped by a heavy bed of quartzite. It marks the transition period between the deposition of limestone below and sandstone above.

The formation takes its name from the town of Bluefield, West Virginia, where it is typically developed, and attains a thickness of 1250 feet. The section at the Narrows is also a little over 1000 feet in thickness. Some horizons are quite fossiliferous in the vicinity of Rich Creek.

The Hinton Formation

This formation is composed of impure limestones, argillaceous shales, sandy shales and sandstones, but it is so heterogeneous that no bed may be mapped separately. It is especially well developed along the New River in the vicinity of Hinton, West Virginia, from which place it takes its name. In Giles County there are 1000 feet exposed, but the section is not complete. There are several fossiliferous zones in this formation. The calcareous beds are rich in flat coiled gastropods. *Stigmaria* and *Calamites* are rather common in some of the divisions.

Tertiary Gravels

Mention must here be made of the Tertiary gravels which are found even at considerable altitudes in the open valley between Butt and Angels Rest mountains. Some of these deposits occur at elevations as much as 350 feet above the present river bed. The exact status of these deposits is in doubt, but they may in part correspond to the Lafayette or Orange Sand formation of Oligocene time, which is found in many of the states just to the west of the Appalachians. This formation often has a thickness of twenty to thirty feet and is composed of sands, gravels, and even rounded boulders. It was derived from the insoluble residue of older formations such as chert and quartzite pebbles, together with limestone fragments side tracked by the streams before wholly ground up. The color is often yellow or orange, and the deposits are quite conspicuous occasionally for long distances. This deposit was formed by peneplanation and

subsequent weathering of the land surfaces during the later Tertiary, producing a layer of loose, insoluble materials. As a result of the several rejuvenations discussed on early pages, the streams could carry more detritus which was dropped on reaching lower levels. This process was repeated again and again with subsequent uplift and erosion. The sediments now are removed from places which have been subjected to severe erosion but are nearly always present in places where streams are too weak to handle the residue. Especially is this true in the Pearisburg area where underground drainage takes care of so much of the water, that surface erosion is lagging far behind subsurface weathering.

STRUCTURAL GEOLOGY

The sedimentary rocks of this county have been extensively folded, and these folds have their elongated axes roughly parallel and trending east by northeast. Many of the upper layers have been worn away by erosion, so that narrow, parallel belts of outcrops, trending in the same direction as the folds, are the common thing. Harder rocks, such as sandstones and quartzites, have resisted erosion and hence are the mountain makers. The valleys between them are usually carved in softer or more soluble strata, such as shales or limestones.

The folds are, for the most part, continuous and may be traced for miles. The same may be said of the faults, which closely follow the axis of greatest folding.

Folding has tended to increase the thickness of the formations along the crests of the structures and, as a consequence, added strength has been given, so that the formation may take up still more of the stress. These beds are, of course, competent, such as the Clinch, Shenandoah, etc. Non-competent beds, such as the Sevier and the Russell, develop smashed, intensely folded areas between the stronger layers. Drag folds become pronounced and small displacements and shearings are common.

The big Peters Mountain fault runs along the north edge of East River and Peters mountains, just outside of Giles County, and brings Cambro-Ordovician rocks in contact with upper Devonian strata. A smaller fault parallels the East River-Peters Mountain break, and runs north of Wolf Creek. It crosses New River just above the rapids at Narrows and proceeds eastward,

passing just north of Kimballton. It seems to be a single fault east of New River but westward it is generally in two steps. In this paper, this fault will be called the Wolf Creek fault. Near the Narrows, Giles and Romney rocks are brought by this displacement in contact with the Shenandoah limestone.

The Saltville fault parallels the southern boundary of the county. It runs through Poplar Hill, Staffordsville, and a little south of the crests of Buckeye and Spruce Run mountains. Everywhere on the southerly side of the fault is the Shenandoah limestone, but on the north, there are Ordovician, Silurian and even Devonian rocks in various places. It seems to be a two-step fault in Buckeye Mountain.

All of the above mentioned faults are of the thrust type, and in each case the older rocks were thrust over younger ones from the southeast. The dips, then, on the southerly side are regularly south-south-east ward, rarely more than 25° in the case of the Saltville fault, and seldom exceeding 35° in the other two previously mentioned breaks. Other faults of Giles County are of the normal type, and are too small to be named, being ordinarily confined to a single member of one formation, with displacements of less than fifteen feet.

Walker Mountain is formed by the upturned edges of the Clinch and Bays formations to the south of the Saltville fault. Buckeye and Spruce Run mountains are formed by the upturned and south dipping Rockwood, Clinch and Bays on the north side of Saltville fault. The crests are on the south limb of an anticline whose axis lies just north of them. In their south slopes these mountains still preserve enough structure to show that they are the remnants of a syncline which was broken by the fault. Thus the strata on the south side of the fault were thrust up many hundreds of feet so that Shenandoah lies against Rockwood and Clinch. This displacement carried the south limb of the syncline and the succeeding anticline (whose axis was between Buckeye and Walker mountains) so high that they were all eroded in the pre-peneplain periods of erosion (probably early Mesozoic time). Walker Mountain, then, is the southern limb of the anticline with the strata dipping away to the south.

Pearis and Angels Rest mountains are opposite sides of a synclinal structure pitching off to the west by southwest, so that Mill Creek is flowing in an erosion widened, structural valley.

Butt Mountain is another part of the same structure pitching in the opposite direction, east by northeast. Between these two summits the structure was so high in pre-peneplain times, that the hard layers, Rockwood and Clinch, were eroded off together with the less resistant ones down to the Shenandoah and Chickamauga limestones. New River found its way across the structure at this place. The roots of the syncline can still be seen in these rocks in the vicinity of Ripplemead.

The limestones making up the valley areas are of course influenced by the above discussed structures, yet in most places the dips are not extreme. However, north of Bane, where the anticline between Pearis Mountain and Buckeye Mountain is folded highest, there is an area where many small pronounced structural features occur, but these have previously been discussed under the heading of the Russell formation.

Sugar Run Mountain and Pearis Mountain converge toward Flat Top Mountain because they stand up on account of the hard layers in the above discussed anticline, which is pitching steeply westward. Flat Top is then the descending crest of this structure as it goes down carrying on its summit Clinch, Rockwood, Giles, Romney and Kimberling.

ECONOMIC RESOURCES

Coal

Giles County may be regarded as a block of older Paleozoic strata separated from younger rocks, on the north, by the Peters Mountain fault, and on the south, by the Walker Mountain fault. For this reason, coal is not found in Giles County, although semi-anthracite coal of good grade is mined but two miles to the south of the Walker fault, in the Cloyds Mountain area of Pulaski County.

Oil and Gas

The possibility of finding either oil or gas in the rocks of Giles County is remote, indeed, and so far as could be discovered there has been no drilling for either of these products.

The strata of this area are so deeply dissected, so complexly faulted and mashed, and so intensely folded that any oil or gas once imprisoned has long since escaped. However, since none of the residual products of the natural distillation of hydrocarbons are found, it is doubtful if they were ever present here.

Manganese[22]

Historical Sketch

The manganese deposits of Virginia have been worked at various times since 1834. However, previous to 1917, no work of a commercial nature was attempted in Giles County. In this year, the Stange mine was first operated and various other smaller prospects in the county were exploited, due to the increased demand for domestic manganese ores on account of the War. When the armistice was signed, work ceased at once on most of the mines, but the Stange prospect was operated until June 1, 1919. This mine, which is one of the most important in the state, is no doubt the prospect described by Boyd[23] some forty years ago as follows:

"Manganese ores seem to be confined almost exclusively to the Oriskany measures. In fact, the iron ore of these rocks frequently gives way almost entirely to oxide of manganese.

"At one point in these rocks on Flat Top Mountain, near the line between Giles and Bland counties, the ore was found in great purity, giving the following measures, etc.: Trend north 70° east, dip 60° north 20° west, containing valuable quantities of manganese disseminated heavily through the sandstone, five hundred yards in length, gradually becoming impregnated with iron as you approach the eastern end. The apparent width of the ore strata here is extraordinary, and may be owing to a duplication of strata from end pressure, or flexure, or a mere fold. It is 240 feet through. Elevation above the water level in Kimberling Creek is 1200 feet; vein would no doubt strip well.

"Analysis of Manganese Ore as follows:

"Red oxide of manganese (Mn_2O_3 ?)	84.34	(a)
Oxygen (O)	3.73	(a)
Protoxide of Cobalt (CoO)	.68	
Alumina (Al_2O_3)	1.80	
Lime (CaO)	.32	
Silica (SiO_2)	.21	
Baryta (BaO)	7.21	
Water (H_2O)	1.71	

(Signed) H. Dickinson."

[22] The material incorporated under this heading has been derived in part from Bull. No. 23 of the Virginia Geol. Sur. by Stose, G. W., and Miser, H. D. and also from private sources of information.

[23] Boyd, C. R., "Resources of Southwest Virginia," pp. 147-148. John Wiley and Sons, New York, 1881.

This description, even in the light of present knowledge, may be regarded as a very good one, and to Boyd must go the credit for first mentioning the manganese deposits of Giles County, at least, in writing.

It may be interesting to digress here long enough to mention the method of discovery of the value of manganese in the manufacture of heavy ordnance pieces. According to Judge Bernard Mason[24] of Pearisburg, many of the large guns used by the South, in the Civil War, were made from iron ore obtained from Giles County and vicinity. This ore contained some manganese, but this fact was either unknown or disregarded by the manufacturers. The fact that the southern canon stood up better under heavy service was known, however, and the war being over, an investigation was made. The results showed that manganese had imparted extra strength to the steel.

The Stange Mine

The Stange mine has marketed slightly more than 2000 tons of ore during the course of its operation. The workings are on and near the crest of Flat Top Mountain, and the boundary between Giles and Bland counties actually passes through the mine. There are three principal cuts: the North cut, which is on the north side of the crest, trends east and west, being about 250 feet long by 60 feet wide and 30 feet deep. The South cut is 600 feet in length and follows the face of the mountain. The Middle cut runs northeast from the South cut about 150 feet and is some 40 feet in width by 20 feet in depth.

The veins and pockets of ore vary greatly in size, the ore being distributed through all the sandstone revealed in the openings, but very unevenly. One ton of ore of market grade can be derived from four to five tons of the ore-bearing sandstone.

The ore as mined by B. T. Johnson and sons, as well as by Mr. Suffern, was either picked up on the surface or mined by hand in open cuts and was then hand-picked for marketing.

Mr. Stange later operated the mine by means of a steam shovel, and then hauled the ore more than a mile to the washing plant on Ding Branch of No Business Creek. The plant consisted of a double log washer and a picking belt. After the ore was run

[24] Private conversation.

through the washer, the concentrates were hauled in trams from the plant to the base of Wolf Creek Mountain. From this point, the ore was carried to First Ford station by means of an incline railroad. Here, it was transferred to standard cars for shipment. Of necessity, this transportation method greatly increased production costs.

The deposit is in the Giles sandstone which is probably of Oriskany age. The sandstone appears on the surface as well as in the workings. There are pockets of ore and sandstone fragments up to ten feet in width, which extend down to some twenty-five feet. These are thought to be zones of fissuring in the anticlinal arch of sandstone, which have become impregnated with ore formed by the accumulation of residual materials in the fissures as the rock weathered.

Scattered masses of ore at the surface indicate that the deposit extends east and west some nine hundred feet and north and south a little over three hundred feet. A drill hole seventy-two feet in depth is said by Mr. Stange to have found the ore continuous at least to that depth. The minerals are manganite, pyrolusite, psilomelane, the last named being most common at the surface. Pyrolusite is the chief mineral found at depth. It is of a fine grade, suitable for metallurgical purposes. The mine has by no means been exhausted, and future developments may be expected as soon as present transportation difficulties are overcome.

Other Prospects

No other prospect for manganese in Giles County approaches the Stange mine in size or possibilities. Pyrolusite float can be found here and there almost any place in the county. On account of this fact, when the war boosted manganese prices, attempts were made to develop a number of prospects which were without commercial value.

Laing Prospects

This prospect is two miles northeast of the village of Newport. Newport is a village in the southeast corner of Giles County, a mile south of Sinking Creek and 7-8 miles east of Eggleston. A group of openings has been made on a hill top about a mile north of Sinking Creek. The elevation is 2600 feet and seems to mark the level of a former peneplain, now largely destroyed. The prospect is underlain by Shenandoah lime (Knox dolomite

of Stose and Miser) and the ore is in the residual clay and chert of this formation. An overthrust fault here has brought these older rocks in contact with sandstones of probably Oriskany age which appear a little higher on the mountain side. Very little actual work has been done here.

Simpkins Prospects

This prospect is two and one-half miles west-north-west of Interior Station on the Potts Valley branch of the Norfolk and Western Railroad. This branch leaves the main line about a mile below Ripplemead and runs up Stony Creek past Kimballton almost to the northeast corner of the county. The openings are on the crest of a spur of Peters Mountain at an elevation of 2800 feet, and the ore appears to be in the fractured zone of the southwest end of the local syncline. The formation in which the ore is found is the Giles, which is here a buff colored, much fractured sandstone. Psilomelane is the ore. Transportation facilities are good since the prospect is less than a mile from the railroad, but there is not enough ore in sight to warrant exploitation.

Stowe Mine

This mine is on the southeast slope of Piney Mountain, four miles to the southwest of Narrows on the Norfolk and Western Railway. The openings are all shallow pits, on or near the surface of a bench which is 2400 feet in elevation. This probably represents the old valley floor peneplain of the New River System.

The ore is in shaly sandstone and clay which appears to be of Giles age. About fifty tons of ore, running 32% manganese have been taken from the mine. This mine can only be worked at a profit when the demand for manganese is greatly increased.

The Bane Prospect

This prospect, which lies just south of Walker Creek at Bane, seems to be little known. However, this prospect is probably the only one in the county (the Stange mine excepted) which has possibilities favoring development in the future.

The ore, which occurs in the residual clay and chert overlying the Shenandoah limestone, is pyrolusite. The area over which the ore appears on the surface cannot be less than forty acres, and, according to local information, several small pits found the ore not decreasing in quantity at a depth of five feet. The

surface mantle of soil and chert contains the ore, hence a wasner would be necessary to prepare the manganese for market.

The nearest point where shipment could be made, is Pearisburg Station, which is some eight miles distant, too far to warrant exploitation at present. However, should a railroad be run up Walker Creek Valley, this prospect would at once become of considerable value, since the quantity of ore is large and can easily be worked by steam shovel.

The Hare Prospect

This prospect is one and one-half miles north of Chapel Station on the New River, Holston and Western Railroad. Two openings have been made, both in the Oriskany member of the Giles, which are about forty feet long by eight feet wide by fifteen feet in depth. Some psilomelane has been mined but the sandstone has been only partially replaced by this mineral and brown iron ore. The latter may become of importance since a pit farther north reveals the ore to be some fourteen feet thick in the Rockwood formation.

Other Locations

Manganese is also reported from many other localities. The Beamer prospect is about a mile east of the Hare prospect mentioned above. No Business Creek prospect is three miles south of Chapel station over Wolf Creek Mountain and while little work has been done here, surface indications suggest a considerable deposit of manganiferous iron ore. Other prospects, similar in nature to the Stange mine, occur farther to the east of this deposit on the same ridge. The Johnson prospect and the Thompson place are both Flat Top prospects somewhat more than a mile to the northeast of the Stange mine. In both places, the ore is low in grade and occurs only in small amounts. However, some twenty-five tons have been shipped from the Johnson mine.

Manganese float is also found in Short Mountain, in the vicinity of Narrows, in the Doe Mountain region, near Newport, and in the Spruce Run Mountain tracts. These prospects have not been exploited and if any ore has been shipped, it has been hand picked from the float appearing at the surface and is almost negligible in quantity.

The Origin of Manganese Ores in Giles County

The important manganese deposits of Giles County occur in clays, sandstones and cherts. Chert, in the Shenandoah, is often stained black by the oxide of manganese which in some cases is present in sufficient quantity to warrant the name of ore. Chert which has been broken into small fragments is often recemented with manganese oxide or even replaced by it. Both the chert and the manganese, being relatively insoluble, have been left behind as residual products of the weathering of the limestone. Some of the deposits are near fault contacts, the concentration being due to the free circulation of ground water in the brecciated zone. However, if we except the deposit near Bane, described above, prospects in the Shenandoah are small and of no great value; in fact, the only mine of this type which has been worked in the county is the one near Newport. It is rather interesting to note that, so far as could be ascertained, ore of this type occurring in the residual clays of Giles County does not show any evident connection with the chert found in association. The connection, however, is obvious in the deposits of the other counties in southwest Virginia.

In Giles County by far the largest deposits of manganese occur in sandstones of the Giles formation or in the unconformably underlying Rockwood sandstones. Crests of anticlines seem to be the favored position for the accumulation of these deposits, due to the fact that these resistant beds, when bent, developed fractures wherein ground water could easily circulate.

Many of the prospects are unique in that they occur on Mountain tops, such as the Flat Top Mountain prospects. Obviously, segregation must have taken place when the present elevation of some 3000 feet was part of a peneplain which was not very high above sea level. Other deposits occur on benches on the flanks of the main ridges. These also were segregated when the present elevation was but a part of a smaller, and later peneplain than that which was developed in Cretaceous time. Of the bench type are the Carrie, Laing, Simpkins, and the Spruce Run Mountain prospects mentioned above.

The association of these ores with particular formations seems to indicate that the manganese was deposited in greater quantity in certain beds than others, yet only disseminated thinly; and that it has been concentrated into its present state, by solution

and redeposition by circulating ground waters as the rocks weathered.

The manganese ore of the Shenandoah was probably widely scattered in the basal portions, originally as a carbonate. Here it was dissolved by ground waters. Solution channels, caving, or folding caused brecciated zones, in which the ore was redeposited in a concentrated form. The interstices were thus filled with ore, and the silica of the chert was in some cases partially replaced by the manganese oxide.

In a similar manner, the ore which is found in the Rockwood and Giles formations was originally disseminated in the basal Giles. The manganese was concentrated by descending, circulating waters and deposited as the oxide near the bottom zone of surface weathering.

The Oriskany iron ores of Virginia have been regarded by Watson[25] and Holden[26] as having been derived from the iron bearing minerals in the Devonian shales overlying the Oriskany. These minerals were dissolved by carbonated waters during weathering and redeposited in lower levels. Watson suggested that the manganese deposits in these rocks might have had a similar origin. Accordingly, he collected a sample of unaltered shales which overlie the manganese of Bland County to determine the absence or presence of manganese. Although the analysis showed 4.54 per cent. iron oxides, no manganese was found.

The absence of manganese in the particular sample of shale collected has been thought to have made this theory untenable. However, despite this fact, we are inclined to the opinion that at least some of the manganese was originally disseminated in the overlying shales as well as in the sandstones of the Giles formation. The reasons for this view may be stated as follows: first, some of the deposits occur well up in the Giles sandstone, so that derivation, in entirety, from the same formation is rather unlikely, and, second, if the iron deposits which are so wide spread in the lower measures are derived from the Devonian shales, whose analysis shows but 4.54 per cent. iron oxides, might not the manganese, whose quantity is negligible in comparison with that of the iron, have, at least in part, the same source, and yet not be detected in the analysis, especially, of a single sample?

[25] Watson, T. L., "Mineral Resources of Virginia," pp. 408-410, 1907.
[26] Holden, R. J., U. S. Geol. Survey Bull. 427, pp. 67-68, 1910.

Iron

Iron ore has been mined in Giles County, and will, in the future, constitute a more important economic resource than it has in the past or does at present. The ores may be divided into three classes: Those found in the Oriskany horizons, the Clinton or Red fossil ore of the Rockwood and the ores found in the lower Paleozoic limestones.

The Brown iron ore is the type usually found in the Oriskany measures. Boyd[27] estimated that ten per cent. of these rocks were iron, but the deposits are of such a local nature that this estimate seems much too high. The most conspicuous beds are found on Buckeye, Butt, Salt Pond and Flat Top mountains. There is also a large deposit on Wolf Creek Mountain, which Boyd thought would yield 300,000 tons of ore, which would run over sixty per cent. metallic iron. Boyd was rather prone to exaggerate and but little has been mined here. At Interior, some mining of Brown ore in Oriskany measure has recently been done, and since the railroad has solved transportation problems, it seems likely that more ore will be mined in the future, as the reserves here are quite large.

The source of these ores has been explained in the discussion of the Stange mine. The Devonian was a period during which much iron was deposited,[28] as is shown by the fact that shales overlying the Oriskany sands will run five per cent. iron content. The concentration of these ores in fracture zones in the lower sandstones is thought to be the origin of the local Oriskany ores.

Hematite ore is found in the Clinton (Rockwood) formation wherever it is exposed in Giles County. The ore is usually the richest in the lower layers just over the Clinch. This is especially true where the Rockwood is the ridge maker, as in these cases the iron of the upper layers has been leached out and concentrated in the fractured lower layers, which overlie the nearly impermeable quartzite below.

The ore is both fossil and granular in type. The fossil ore is made up of aggregates of broken fossils, which were originally calcium carbonate, but which have now been replaced by ferric oxide, some of which was always present in the formation, prob-

[27] Boyd, C. R., "Resources of Southwest Virginia," pp. 144.
[28] Emmons, W. H., "Principles of Economic Geology," pp. 295.

ably filling cavities. The granular ore (which is usually subordinate to the fossil type) is made up of aggregates of quartz grains like flaxseed in shape, about which the iron oxide has been deposited. In the Clinton epoch, iron was deposited in large amounts throughout much of eastern North America. This ore was carried in solution as bicarbonate in the presence of carbon dioxide. When the excess carbon dioxide was removed, ferric hydroxide was either precipitated due to oxidation and hydrolysis, or on account of the iron bacteria, which according to Harder[29] are always active in its accumulation.

The Bays Formation (Upper Ordovician) is often ferruginous, and Bassler has suggested that at least some of the iron of the Clinton is due to the erosion of the Bays, together with the solution of its iron content, and its subsequent concentration in the Rockwood. In a like manner, much of the Devonian ore may be due to the erosion of the Rockwood and the later deposition of the iron content in the Giles sandstones and shales.

The deposit of this type of ore over the entire flat summits of Angels Rest and Pearis mountains may sometime be developed. There are many thousands of tons of poor grade ore in this deposit which might be mined by steam shovel. The small iron content and the lack of any facility to get the ore down off the mountain prevents the exploitation of this ore body.

Many of the Brown ore deposits in the Cambro-Ordovician limestones appear to have been formed rather recently, probably during Tertiary times. (Tertiary fossils have been found in these deposits.)[30] These ores are alteration products of iron carbonate and pyrite, which in turn originated by replacement of the limestone. The ore often is found filling fissures and concentrated in fracture zones. From the structural position of many of the ore bodies, it seems evident that the deposits were made when the country had reached a topographic state not vastly different from that existing today.

The best exposures are at Johnson's near Chapman's Ferry, and at the mouth of Big Stony Creek. Scattered out-crops of this ore are found over the entire county. Usually the stratigraphic position of the ore is near the contact of the Shenandoah with the Chickamauga.

[29] Harder, E. C., "Iron-depositing Bacteria and their Geologic Relations," U. S. Geol. Survey Prof. Paper No. 113 (1919).

[30] Eckel, E. C., U. S. Geol. Survey, Bull. 400, pp. 145.

Thus while the county has a good deal of iron ore and much more ferruginous rock which may some day be leached to make valuable ore, yet there is really no deposit of iron ore known that can compete with the producing regions of the United States.

Limestone and Cement

The limestones of Giles County are of great importance since they may be used either in the manufacture of lime or cement, or as building or road making stone. The New River Lime Company has a quarry to the northwest of Ripplemead, along the river, from which is taken some forty car loads a day. Clay Mason has a considerable lime making establishment across and a little upstream from this quarry. At various times, the limestone has been used in other places but the industry has not been developed nearly to the limits of its possibilities. Cement could be manufactured quite to advantage here, since the Chickamauga exposures are all well served by railroads, and the necessary shale is usually found close at hand in the Sevier formation.

Clays and Shales

These are of little importance here and have not been exploited.

Sands and Gravels

These belong in the same category as the above list. Some sand is taken from the New River for local use, but it promises no importance. Tertiary gravels occur, but are of little use, being composed of large boulders, of cobble stone size, for the most part.

Water Supply

As would be expected in a mountainous, limestone area, receiving considerable rainfall, there is an abundance of water. This supply is very liable to contamination, however, on account of the great development of under-surface drainage. There are several places along the New, where water power could be obtained by tunneling, but an abundance of cheap electric power, due to the nearness to the coal fields, has so far, hindered this. Sulfur and mineral springs occur at Eggleston and at other points.

Soils

For the most part in this area, the soils and the rocks from which they are derived, are equally differentiated, so that the areal map may be followed with considerable accuracy. The sandy soils derived from formations such as the Bays and the Clinch are of no importance for agricultural purposes. For the most part, shale does not disintegrate into a fertile soil; however, the Sevier shale contains enough calcareous material to make it quite productive. This formation, however, usually outcrops so high and on such steep slopes that it ordinarily cannot be used. The Chickamauga ranks the highest as a soil producer and is responsible for the rich farming lands of the Pearisburg area. The Shenandoah limestone also disintegrates into a fairly fertile soil but it also leaves behind it a mantle of the insoluble chert which makes cultivation difficult, but not impossible.

No doubt the soils of the county constitute, at present, the most valuable geologic resource available.

RESUME OF GEOLOGIC HISTORY

As has been mentioned in the introduction, the area under discussion lies in that division of the Appalachian Highlands,[31] known as the Appalachian Valley Province. Giles County is situated at the extreme southern end of the Middle Section of this province. In northwestern and in the central western portions of Virginia, there is no great difference in the stratigraphic succession or in the lithology of the Ordovician and Silurian strata. In the area comprising most of southwestern Virginia, however, a new factor is introduced in the study of these same rocks. Ordinarily, rocks deposited synchronously in comparatively small areas exhibit no great differences either in fossil fauna or in lithologic aspect. In the division of the state mentioned above, the rocks differ in different areas, in both of these respects. In the eastern portion of the great valley, the development of the Ordovician strata is entirely different from that found in the westernmost portions of the state. In studying the various sections, these discrepancies in apparently the same age of strata are encountered in traverses made across the valley rather than in directions paralleling the length of the valley.

[31] Physiographic Divisions of U. S. Ann. Assoc. Amer. Geog. Vol. VI., pp. 19-98.

The theories for this distribution of strata in separate areas will not be developed in this paper any more than to mention that Ulrich and Schuchert,[32] in their Paleozoic Seas and Barriers, have advanced the well founded idea that the area of the Appalachian Valley during Ordovician times was divided longitudinally into several narrow troughs, which were rather effectually separated, one from the other and that the observed differences in sedimentation and faunal life may thus be explained.

The area covered in this survey lies entirely within a single one of these "troughs" but as one ascends the New River and comes to the Giles-Pulaski County line, there is noticed at once a marked difference in faunal life and lithologic aspect. The details cannot be discussed here but it might be interesting to note that the Clinch formation in Gap Mountain, is composed of three distinct quartzitic ripple making layers, while at the Narrows, a scant twelve miles to the west, there are but two of these layers and one of these is not distinct.

The Appalachian series of folds, probably trace their origin to pre-Cambrian times. Walcott[33] demonstrated the existence of a long trough, which during Lower Cambrian times extended from Alabama northeast to Labrador. This was no doubt what we would call a geosyncline and was within the southeastern border of a large Algonkian continent. It was during this time, that the impure limestones and variegated shales of the Russell formation were deposited. At varying intervals, the seas were deep and then again they were shallow, until in Middle Cambrian time, the Appalachian trough was almost drained of its sea. However, long before the close of this epoch, a new period of subsidence was inaugurated, and the sea became gradually deeper until in Upper Cambrian time it was beyond the Adirondacks and had made connection with the Atlantic by way of the restricted Appalachian trough.

For the most part, the Upper Cambrian seas laid down great beds of limestone, which are usually dolomitic and non-fossiliferous. These facts seem to indicate that the Shenandoah limestone, which was laid down at this time, was deposited at a considerable distance from the shores and in waters which were of a considerable depth. Chemical precipitation will be regarded

[32] Ulrich, E. O. and Schuchert, Charles, "Paleozoic Seas and Barriers in Eastern North America." N. Y. State Museum Rept., Bull. 52, pp. 633-664.
[33] Walcott, C. D., U. S. Geol. Surv. Bull. 81.

as the main source of the material which composes it. Between the limestones of this time and those of Beekmantown age in the area under discussion, the difference is very slight and it must be regarded that the sedimentation went on almost uninterupted from the beginning of the Upper Cambrian to the close of the Beekmantown. We will regard the deposition of the Shenandoah limestone, then, as having taken place during this interval. The close of the Beekmantown marks the beginning of a new arrangement in Eastern North America.

A new fold was developed, nearly parallel with, and a little within the western border of the original Lower Cambrian trough and another fold, mentioned before as having emerged early in Middle Cambrian time, was accentuated. Between these two folds, a trough was formed which extended from Alabama to Quebec. It is doubtful, however, if this trough was ever again completely submerged after Beekmantown time. Ulrich and Schuchert have named the western one of these two folds, the Appalachian Valley Barrier, and the eastern one was named the Chilhowee Barrier. The Lenoir bay, which was the southern third of the space between the two folds, occupied a synclinorium containing several disconnected folds, which were high enough to affect the direction of currents, and consequently the character of sedimentation. In a general way, these deposits may be divided into an eastern trough (Athens trough) and a western one (Knoxville trough). The members of each overlap or grade into each other on account of differential warping.

The area under discussion lies in the Knoxville trough. The development of the Chickamauga limestone here indicates that there was at the time of deposition of its bottom layers enough warping to permit portions of the older Shenandoah to be subjected to erosion. The breccia which goes to make up the lower layers of the Chickamauga formation in this area is made up of angular fragments of chert which is identical with that found in the Shenandoah of today. That this chert in the breccia was derived from the older formation is evident and that it was carried but a short distance is evidenced by the fact that the fragments are always angular and in the upper layers of the breccia are seldom in contact one with the other.

The Chickamauga of this area, that is, of the Knoxville trough, contains a fauna wholly distinct from that of other Chickamauga

series, one of which has its greatest development in East Tennessee. In this (the Pearisburg area) locality, however, the Chickamauga embraces every important member of the formation as developed in Tennessee. There is evidence of only a small unconformity between this formation and the Shenandoah, and yet, if we have correctly correlated these strata, a considerable time break exists. This is no doubt represented in part by the breccia described above.

Following the Chickamauga is the Moccasin limestone, which is calcareous near its base, but which becomes very arenaceous near the top. This formation is clearly a gradational one representing the time between the deep seas in which the Chickamauga was deposited and the shallow seas wherein the Bays was laid down. It is due no doubt to the gentle uplift which began in the time just preceding the early Trenton. In the eastern trough we have, as the equivalent of the Moccasin, the Tellico sandstone. After this time, the Sevier formation was deposited quite uniformly in both troughs. The Sevier in its various divisions is equal to the upper Utica, and the Eden, and as would be supposed, grades from calcareous at the base to arenaceous at the top. The Sevier (as well as the Moccasin) may be regarded as an intermediate formation fore-running the Bays.

At about the end of the Trenton, the troughs were elevated quite rapidly and as a consequence, communication with the Atlantic was cut off at the south where the elevation was the greatest. At the same time, the middle portions of the Lenoir Trough sank and permitted the waters from the Mississipian sea to invade. The result of this revolution is the Bays and Clinch sandstones as well as the lower and non-ferruginous shale members of the Rockwood. The southern end of the trough continued to be uplifted as is shown by the fact that of the three mentioned formations, the Bays extends farthest to the south, the next, not quite so far and the third, the Rockwood, falls still short of the Clinch. In spite of the fact that there is an unconformity between the Rockwood and the Giles, (indicating uplift and erosion in Giles County) when Devonian sediments were laid down, the seas were again deeper in this area than off to the south. This is clearly shown by the fact that these sediments are but 25 feet thick at Chattanooga yet are nearly 5000 feet in thickness on the New River.

Mississippian and Pennsylvanian rocks were laid down in Giles County, but have been subsequently eroded. There is no direct evidence for making this assertion, but Pennsylvanian rocks are found on either side of the county, and since faulting has so raised the entire area that Shenandoah lime is in contact with Kimberling shales, there has been every opportunity for erosion to have removed these later Paleozoics.

After this time, the uplift was rather steady and Giles County becomes a land mass. Folding and faulting were not pronounced in the Mesozoic, and by the end of this era a great peneplain had been reached. However, in Oligocene time upwarping began along the Appalachian axis and continued throughout the epoch. As a result, the stream gradients were increased and erosion began apace. As a result, the Tertiary Gravels were deposited in those areas where the stream currents were abruptly checked. The uplifts in the several periods of movement were continuous, but gradual, as is evidenced by the fact that the New River has been able to maintain its course through the ridges which are due to the hard layers.

The rocks of Giles County suffered no close folding during the Paleozoic because, while unconformities can be found, the angular type is inconspicuous. There are no typical continental deposits in the county unless we except the Tertiary Gravels mentioned above. The Clinch has been regarded as a delta deposit and its shape and lithologic character in many areas seem to confirm this view. Here, however, the presence of a marine fossil, (Lingula cuneata) as well as shaly layers indicates that the formation is at least semi-marine, and if it is a portion of a delta deposit, it is the extreme outer edge of such a formation.

Mud cracks are common in many of the formations showing shallow seas, yet marine fossils are also found in these same horizons. Rapid changes of conditions are shown by the presence, in some places, of limestone breccias, as well as fissile shale partings in the great limestones.

The chert in some of these limestones seems to be a surface feature, as deep quarries run out of the chert zone. The presence of chert everywhere in deep caverns may or may not be regarded as an additional proof of the surface character of the chert. Calcite is also secondary in these limestones and is regarded as Mesozoic or Tertiary in age, having formed everywhere in the

fractures developed in the competent limestones during the time of folding. That it is younger than the chert, is often shown in specimens where the chert, as well as the limestone, has been cut by a calcite vein. Hence some of it must be very recent. The age of the iron ores has been discussed, but it may be added that they sometimes seem to be both secondary and primary.

In conclusion, it should be said that this paper has but merely touched upon the geology of Giles County. Scores of problems stand out boldly bidding for solution, while many others lie half concealed and shyly invite attention. Not the least of the problems available are those connected with the ancient life. In this area, the fauna is different from the fauna in the next county to the south. The comparison of the development of contemporaneous life in isolated basins, which are yet not far distant from each other, may go a long way in the solving of some of the problems of evolution. When this work is at last undertaken, the area about Giles County will be a geologist's "happy hunting ground."

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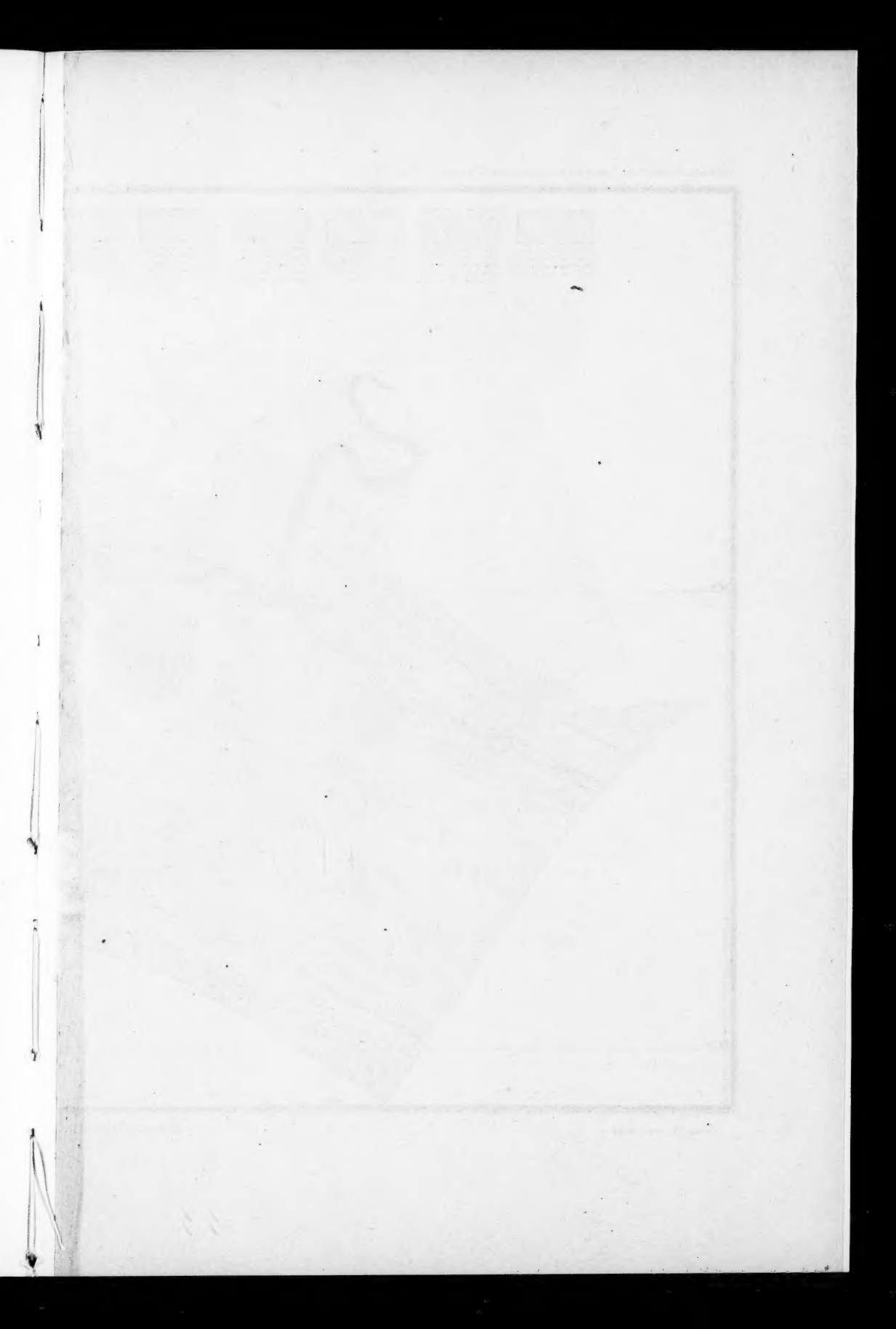
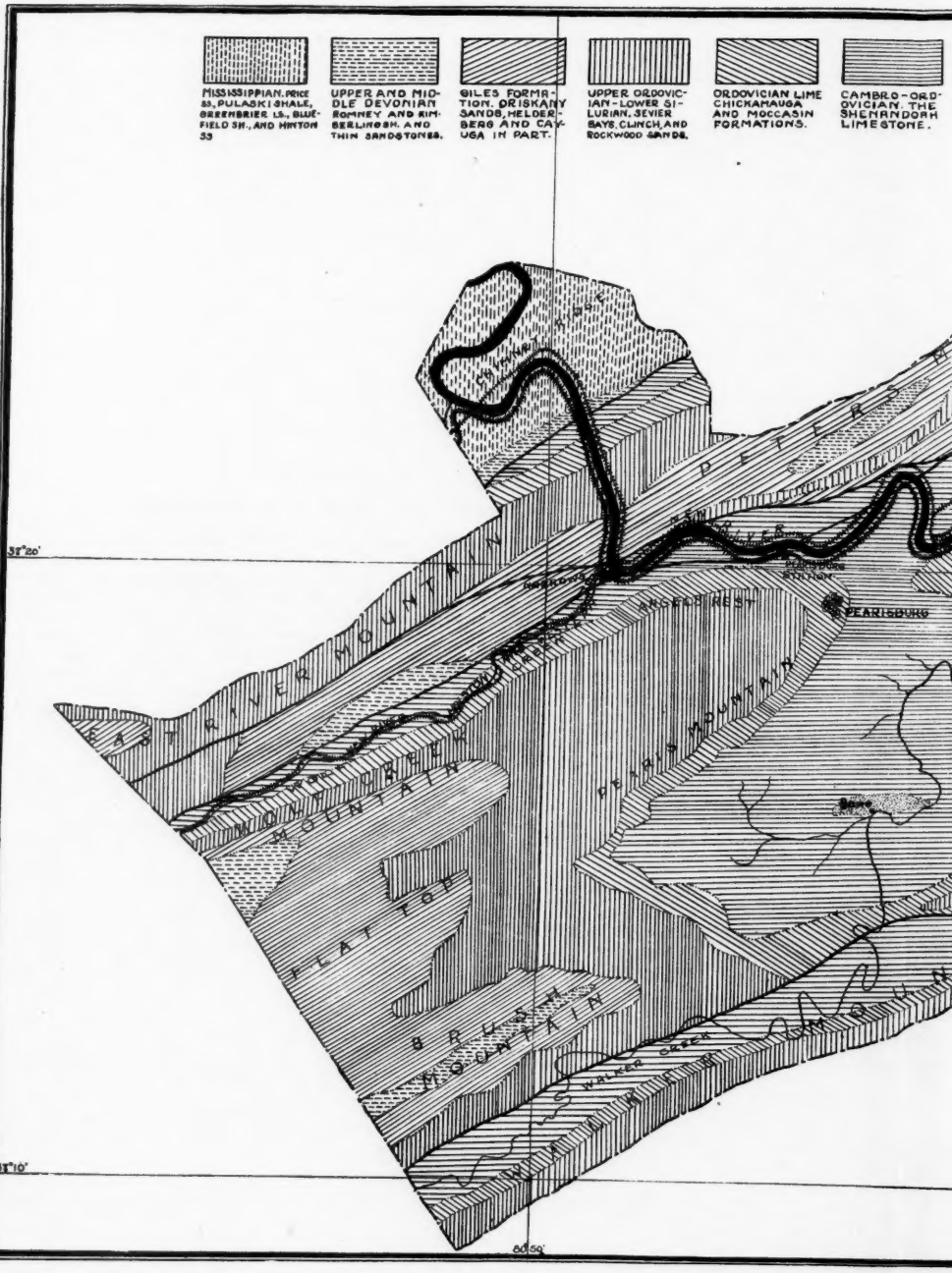
PLATE XLIII

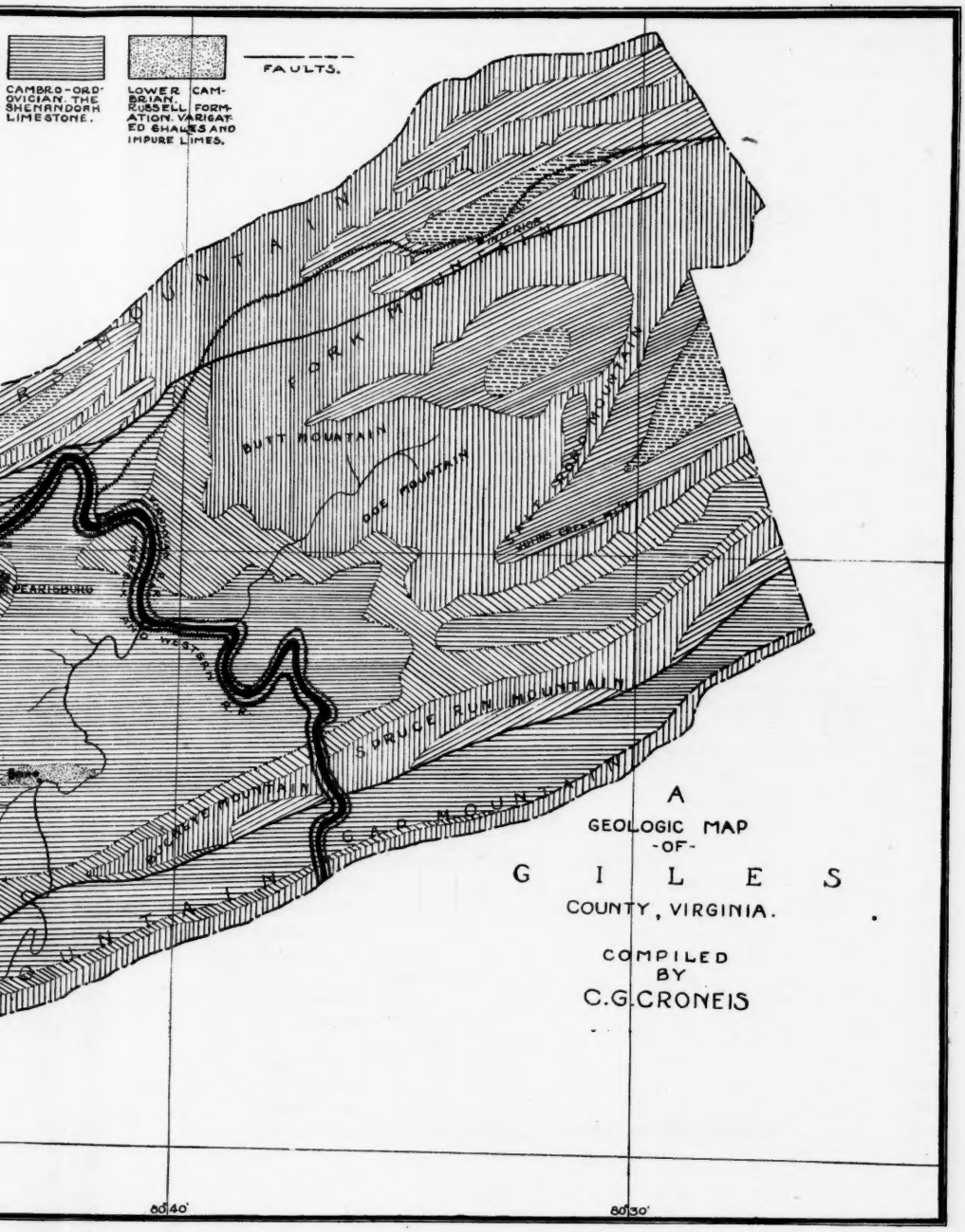
Note on sources of Geologic Map of Giles Co.

This map was compiled from (1) Watson's State Geologic Map of Virginia, (2) a map issued with Stose & Miser's "Manganese Deposits," (3) an old map by J. J. Stevenson, published in Transactions of Amer. Philosophical Society and (4) the work of the Class of 1922.

The manuscript maps by other classes were not used because this map was completed before the accompanying manuscript had taken its present form. The additional data on other MSS. maps would not make much difference in a map on this scale and refinement but in a larger scale map with formational units several areas of Romney, Giles, and Rockwood must be changed. The authors.




MISSISSIPPIAN. PRICE SS., PULASKI SHALE, GREENBRIER LS., BLUEFIELD SH., AND HINTON SS
UPPER AND MIDDLE DEVONIAN ROMNEY AND RIMBERLING SH. AND THIN SANDSTONES.
GILES FORMATION. ORISKANY SANDS, HELDERBERG AND CAYUGA IN PART.
UPPER ORDOVICIAN-LOWER SILURIAN. SEVIER BAYS, CLINCH, AND ROCKWOOD SANDS.
ORDOVICIAN LIME CHICKAMAUGA AND MOCCASIN FORMATIONS.
CAMBRO-ORDOVICIAN. THE SHENANDOAH LIMESTONE.
CRANWELL KNOB
PEFFERS
PEARISBURG
EAST RIVER MOUNTAIN
MOUNTAIN
FLAT TOP
BRUSH MOUNTAIN
37°20'
37°10'
6059'



A
GEOLOGIC MAP
-OF-
G I L E S
COUNTY, VIRGINIA.

COMPILED
BY
C.G.CRONEIS

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